Accelerator R&D in Europe

Subject → Advanced Accelerator R&D

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Helmholtz Distributed ARD Test Facility

Coordinator European Network for Novel Accelerators
(EuroNNAc)

Deputy-Coordinator European Coordination for
Accelerator R&D (EuCARD2)

Accelerator R&D HEPAP Subpanel
SLAC, 29.8.2014

Accelerator Research and Development
ARD
A program by the Helmholtz association

HELMHOLTZ | ASSOCIATION

European Network EuroNNAc for Novel Accelerators

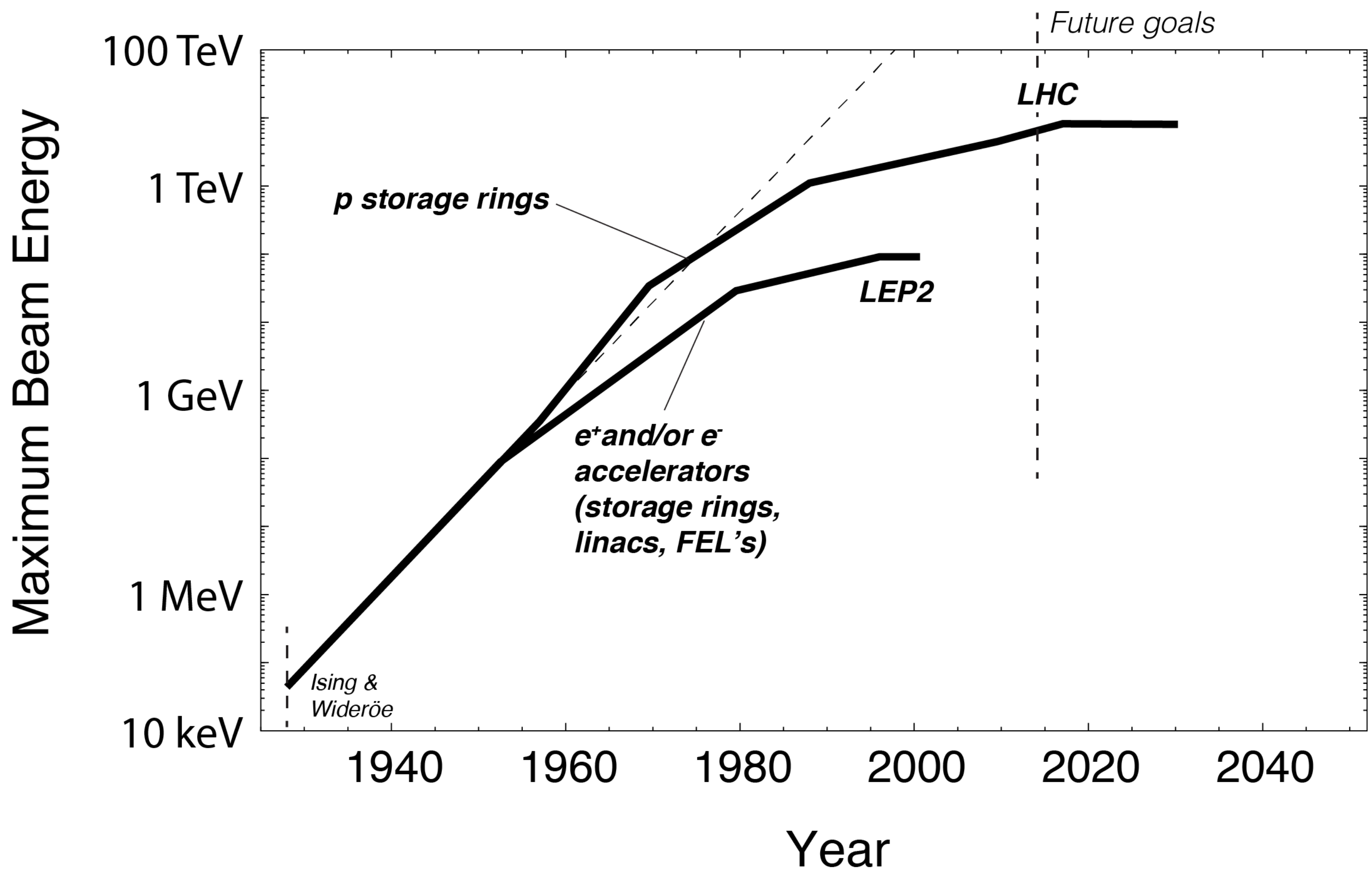
EuCARD²

DESY

Outline

- **Accelerators at the Energy Frontier**
- Accelerator Builder’s Challenge
- EuPRAXIA – Proposal for a European Plasma Accelerator for Users
- Helmholtz ARD Program
- Conclusions

Livingston and Accelerators at the Energy Frontier



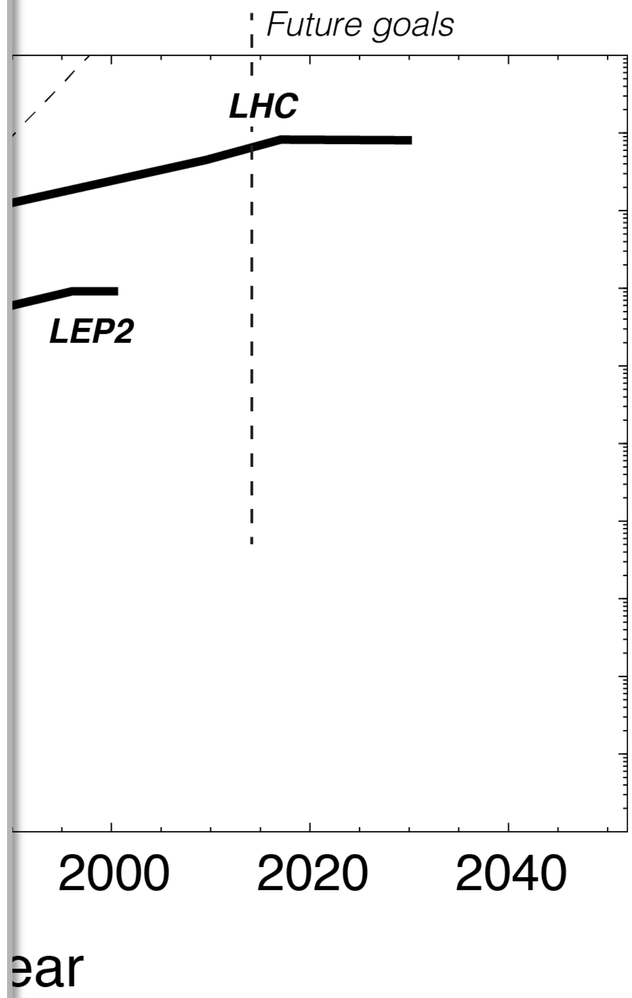
Livingston and Accelerators at the Energy Frontier

Why this saturation?

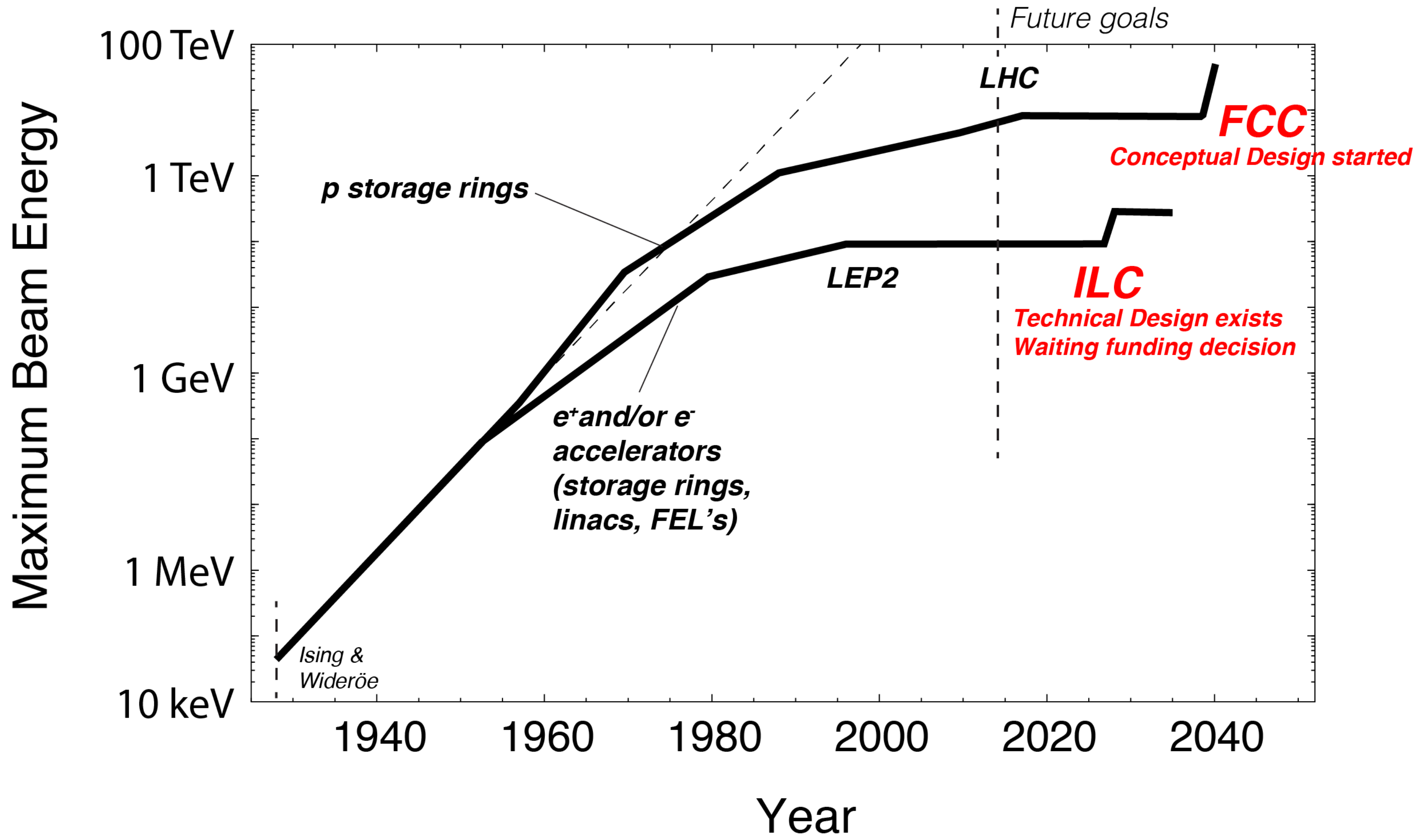
1. Conventional accelerators have reached **<u>hard physical limits</u>**.

2. Energy is extended by scaling or modestly extending proven accelerator technology. As a consequence, **<u>length and project cost also scale with energy</u>**.

3. Ever bigger projects require more time to bring.



Livingston and Accelerators at the Energy Frontier



Livingston and Accelerators at the Energy Frontier

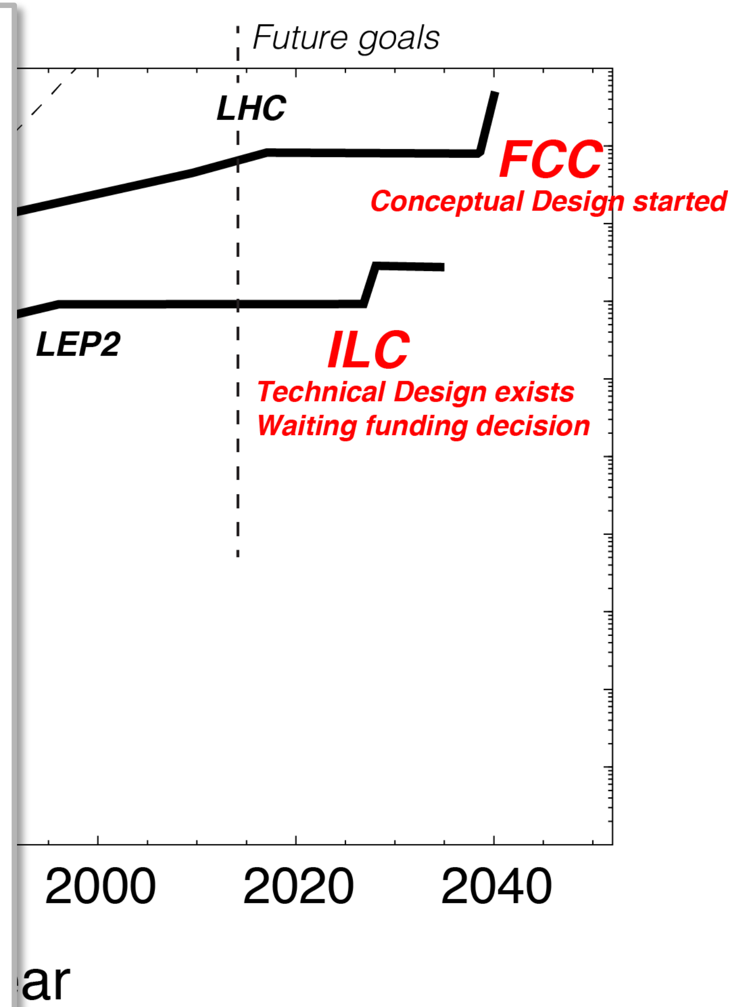
ILC project for the 2020's/2030's.
FCC project for the 2030's/2040's.

1. Timelines reflect the size, complexity and cost of projects (scaling effects).

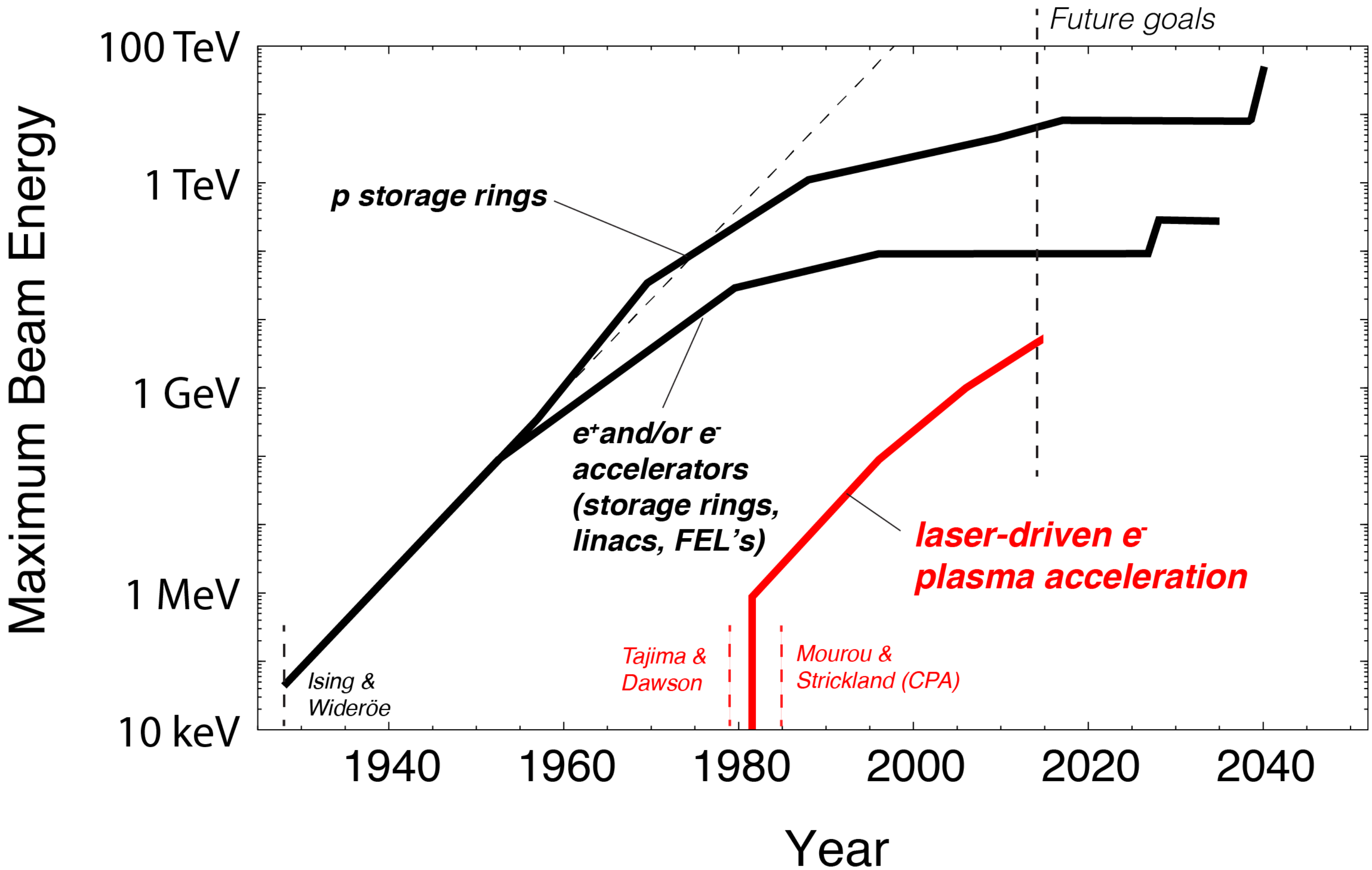
2. These **<u>projects will be very mature</u>** and their performances cannot easily be matched by novel accelerator technologies.

3. However, it is possible that the required funding for ILC or FCC cannot be obtained.

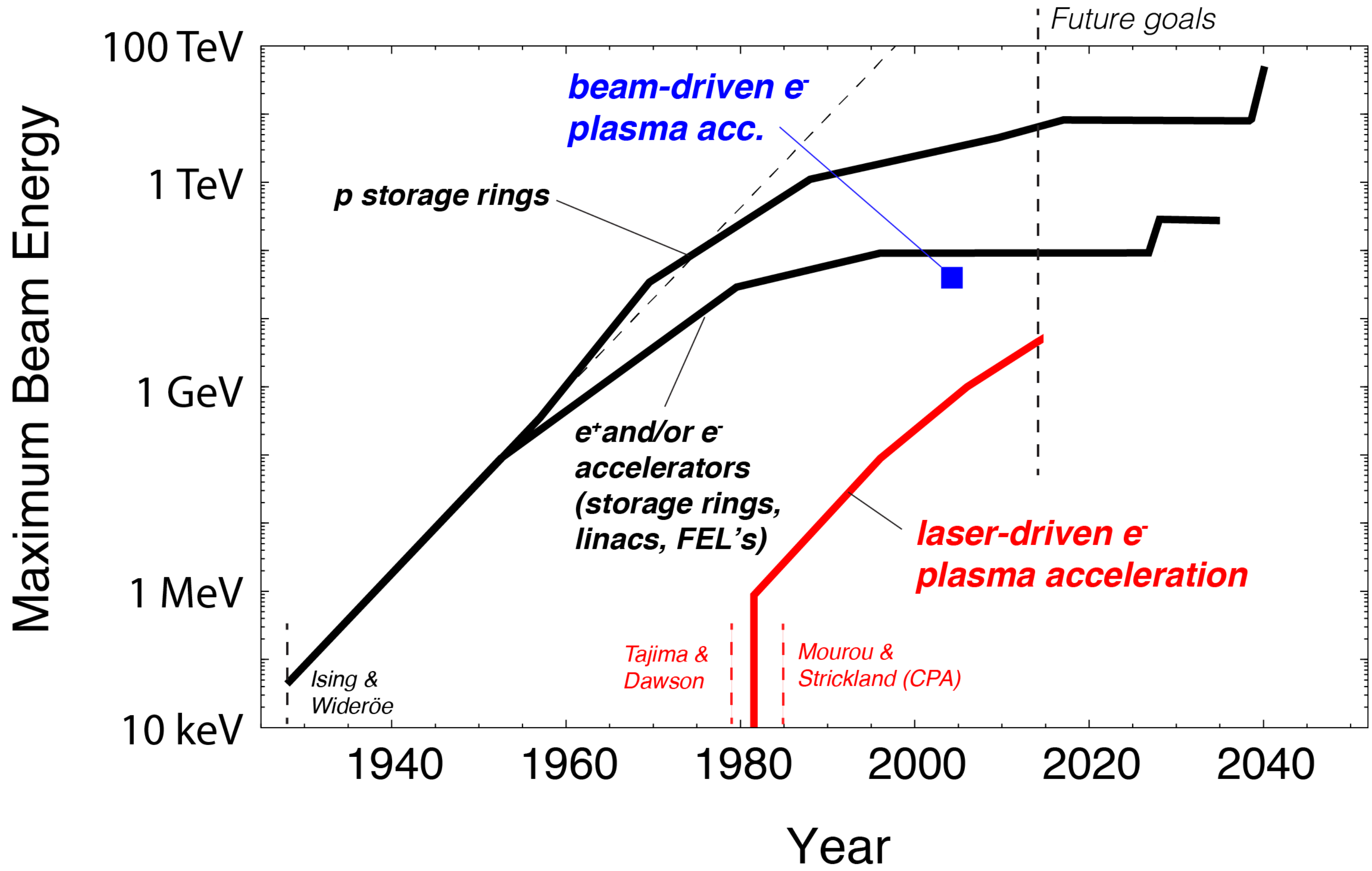
4. In this case it will be crucial to have a **<u>plan B HEP accelerator project in the 2030's</u>**.
   a. This project will likely be less performant than ILC.
   b. This project should also be much smaller and much lower cost.



Livingston and Accelerators at the Energy Frontier



Livingston and Accelerators at the Energy Frontier



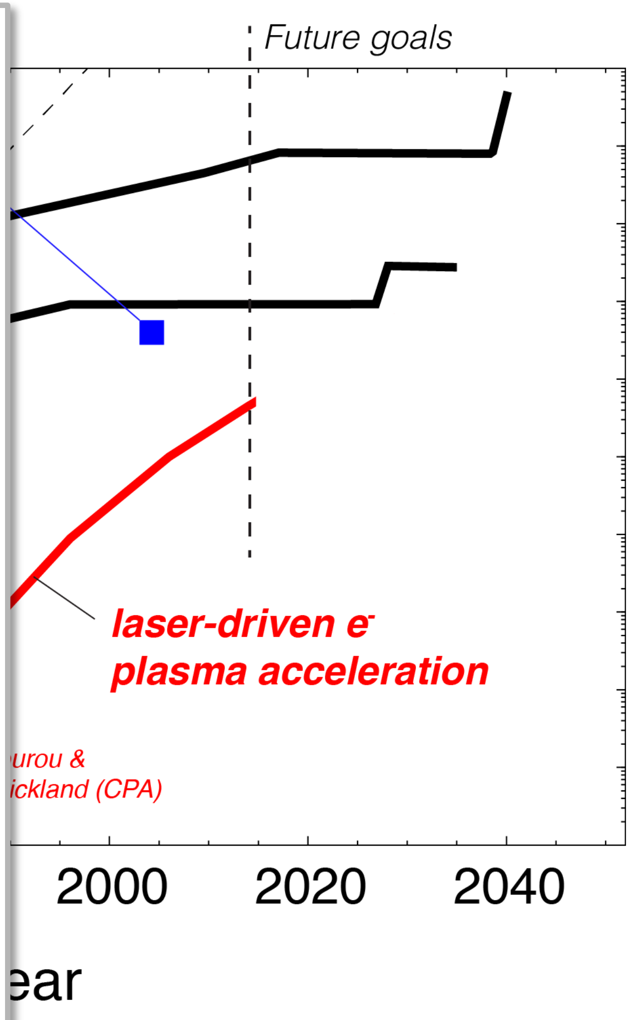
Advent of plasma acc.:

1. Metallic cavity walls replaced with plasma walls → overcoming hard physical limits of metallic RF structures.

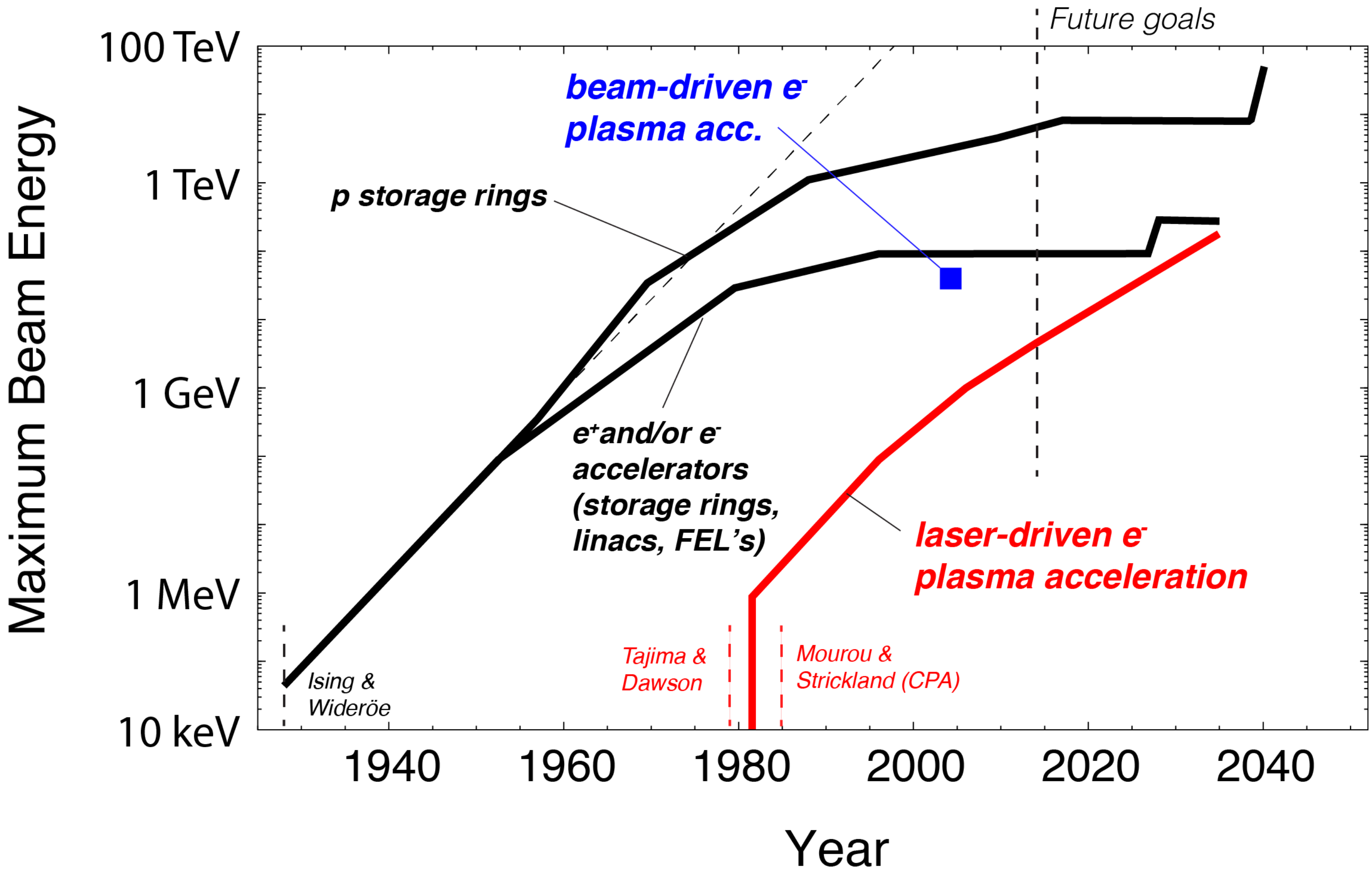
2. Acceleration lengths (same energy) are **factor 100 – 1000 shorter.** Multi-GeV e- beams proven.

3. Still short-comings but **no fundamental limit**.

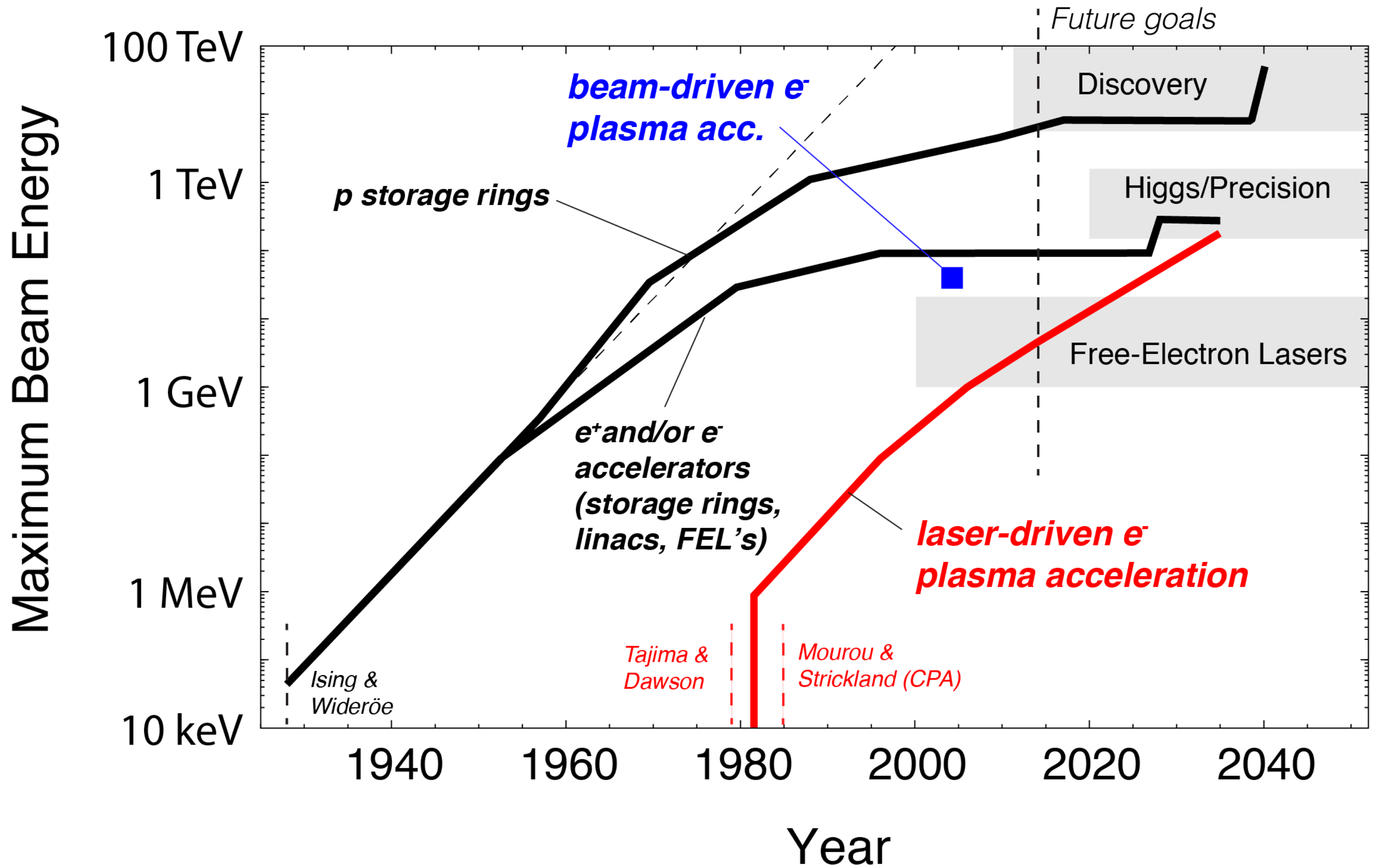
4. Financial effort in HEP at or below 1% of total. **More resources will lead to faster progress**.



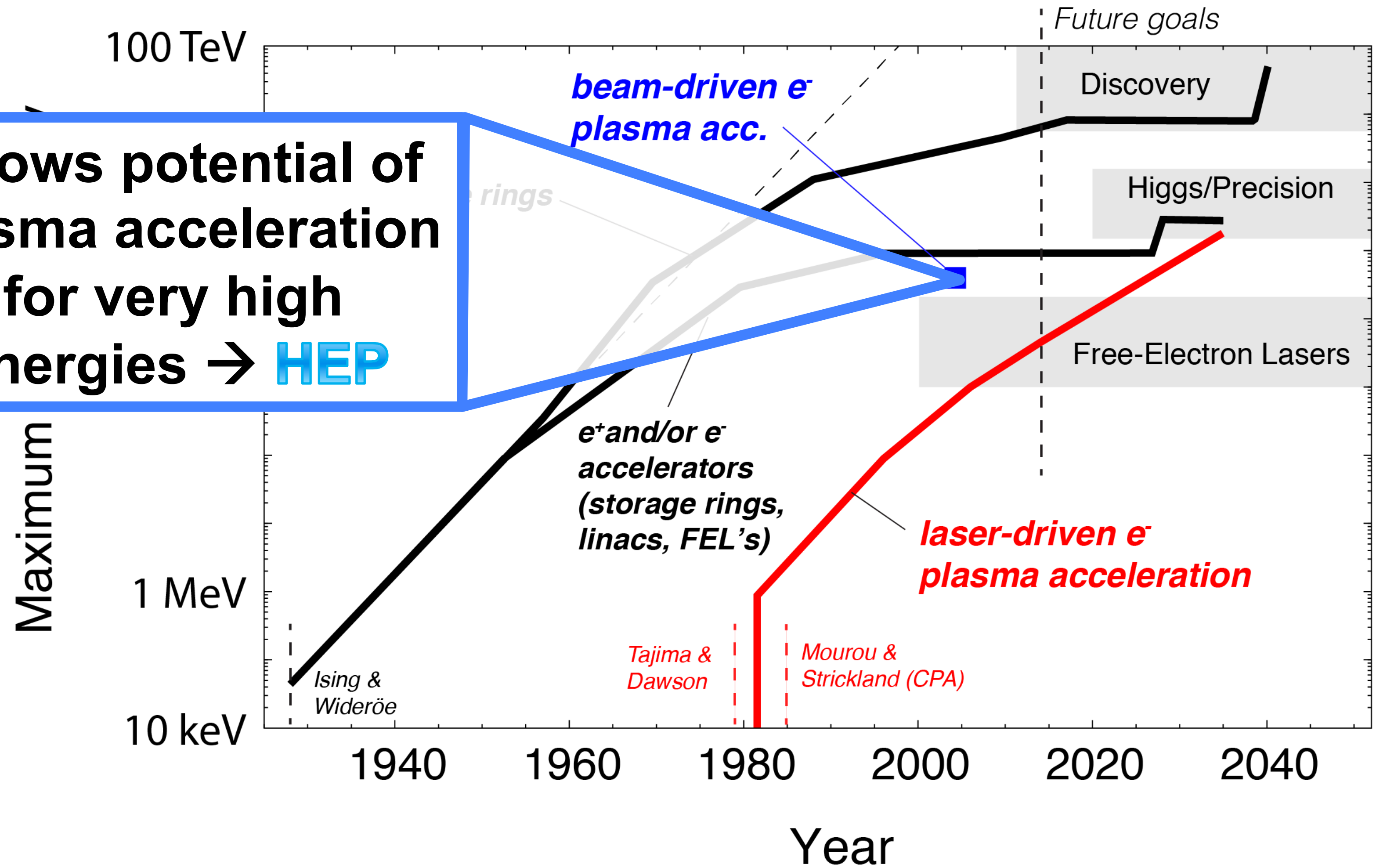
Livingston and Accelerators at the Energy Frontier



Livingston and Accelerators at the Energy Frontier

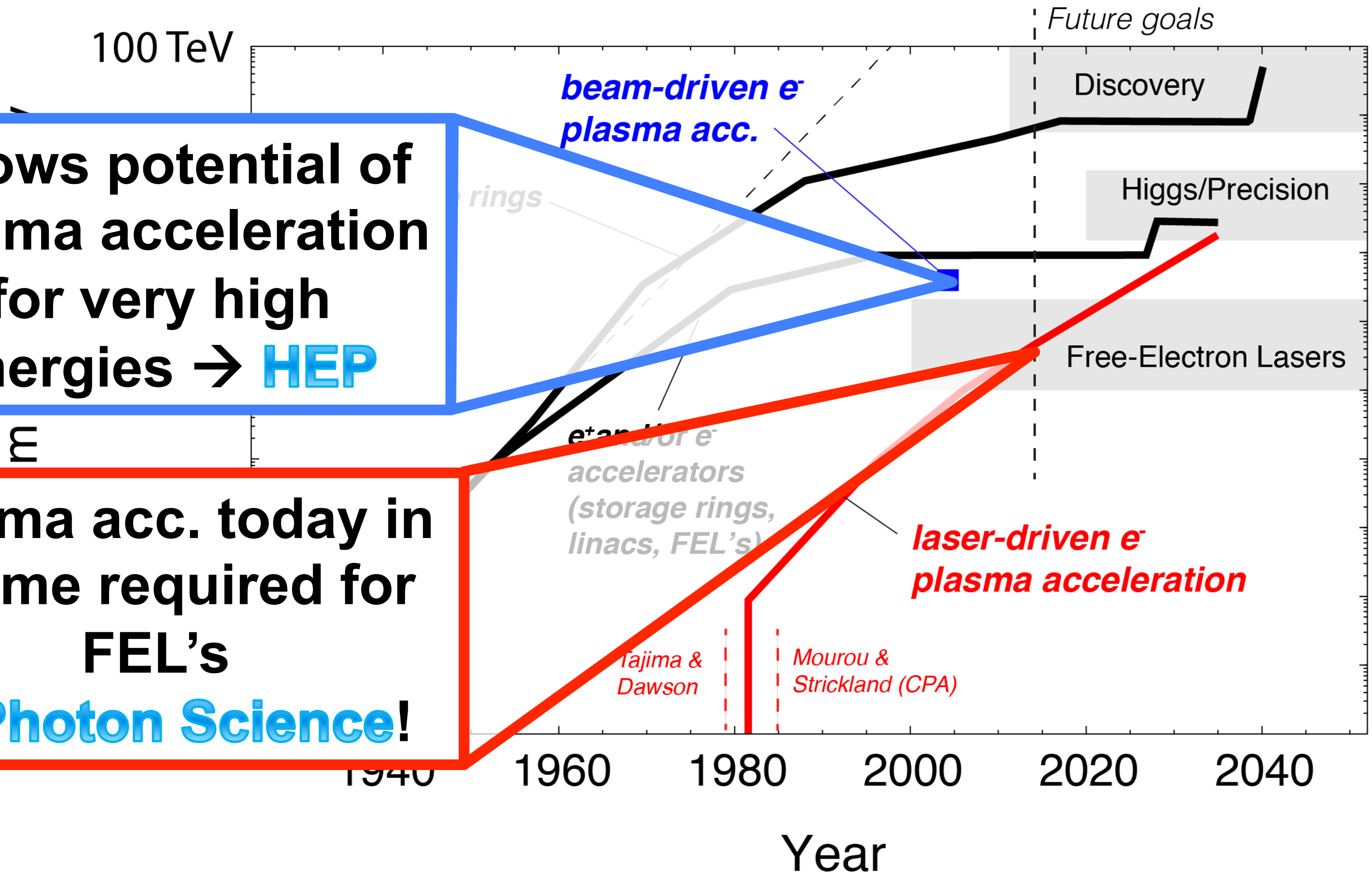


Livingston and Accelerators at the Energy Frontier



Shows potential of plasma acceleration for very high energies → HEP

Livingston and Accelerators at the Energy Frontier



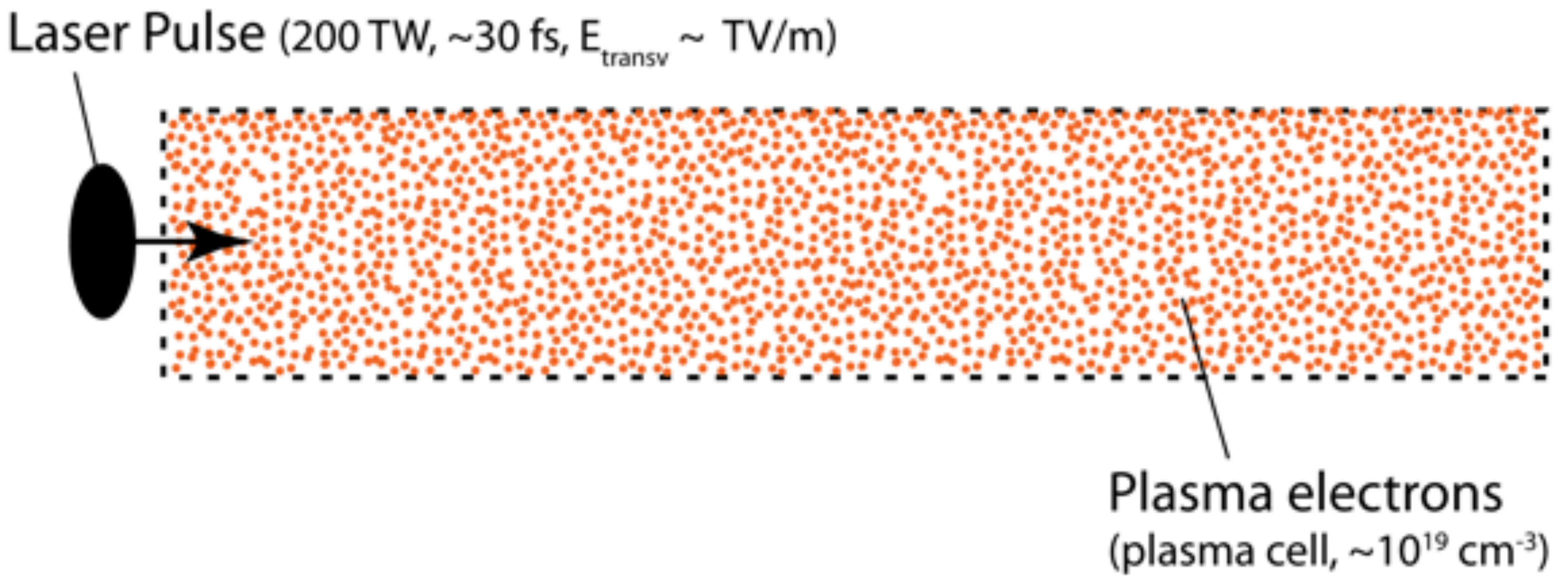
Shows potential of plasma acceleration for very high energies → HEP

Plasma acc. today in regime required for FEL's → Photon Science!

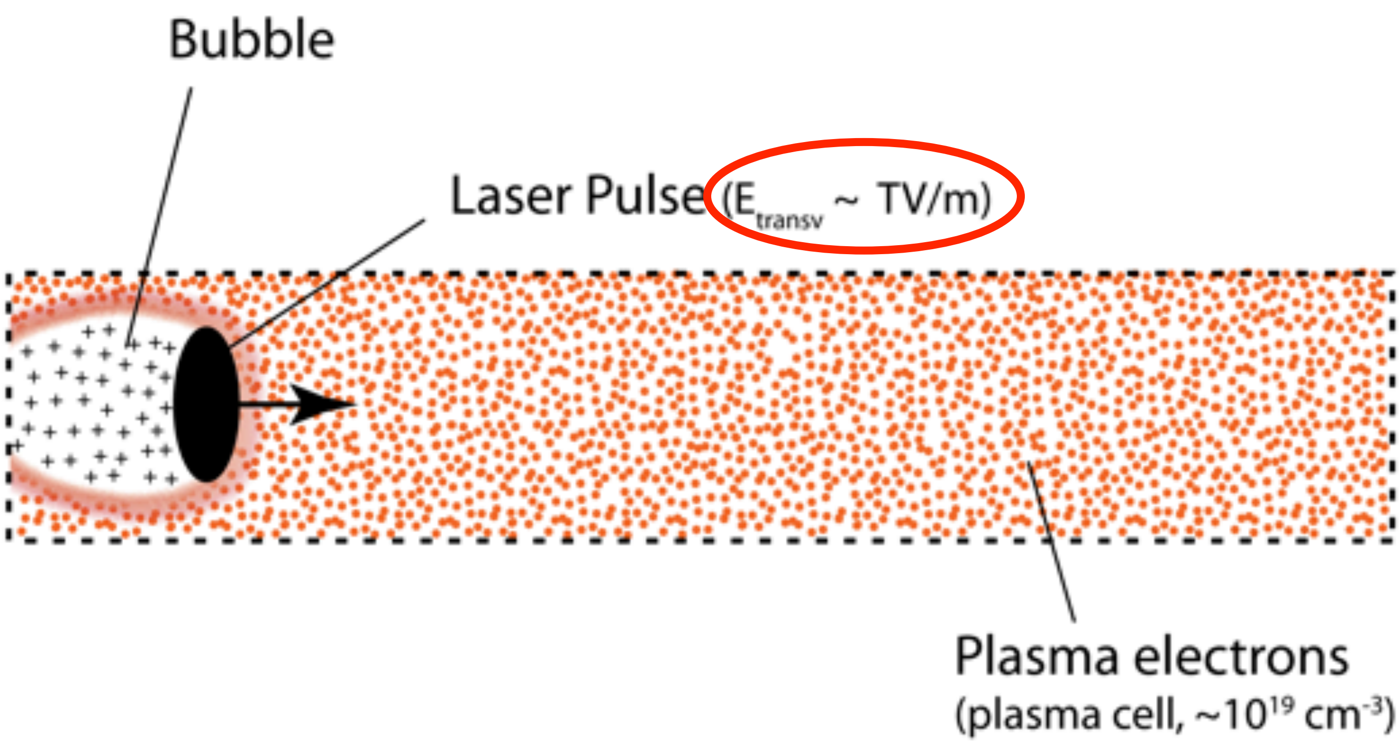
Outline

- > Accelerators at the Energy Frontier
- > **Accelerator Builder's Challenge**
- > EuPRAXIA – Proposal for a European Plasma Accelerator for Users
- > Helmholtz ARD Program
- > Conclusions

Reminder: Plasma-Acceleration (Internal Injection)



Reminder: Plasma-Acceleration (Internal Injection)



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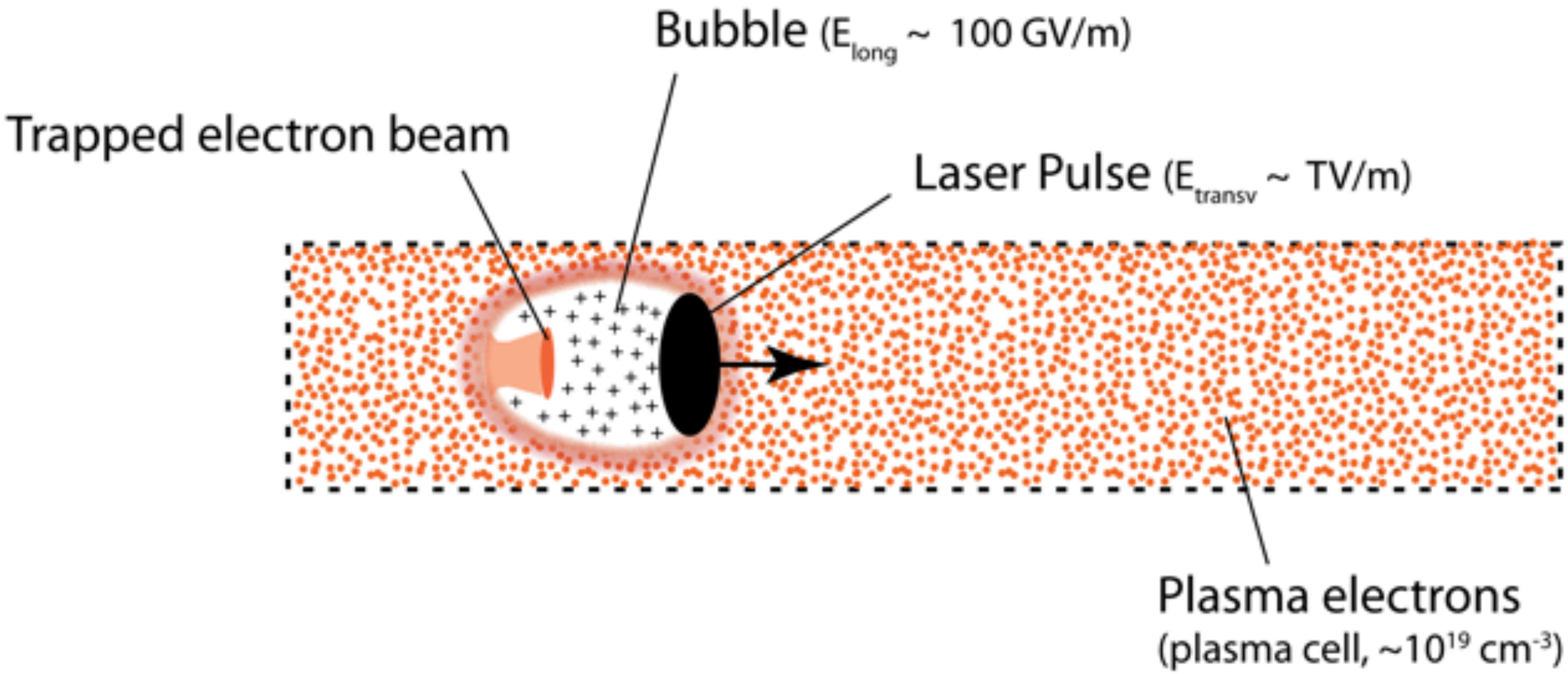
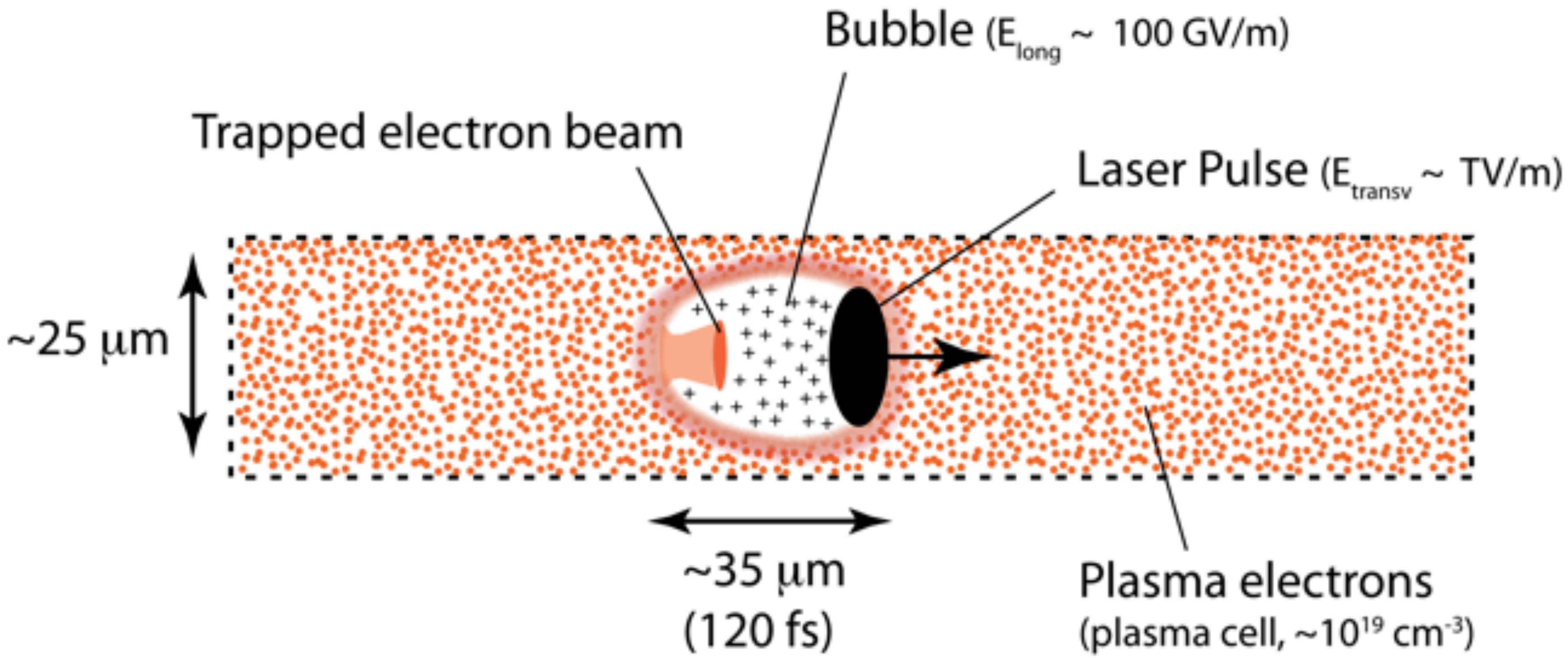
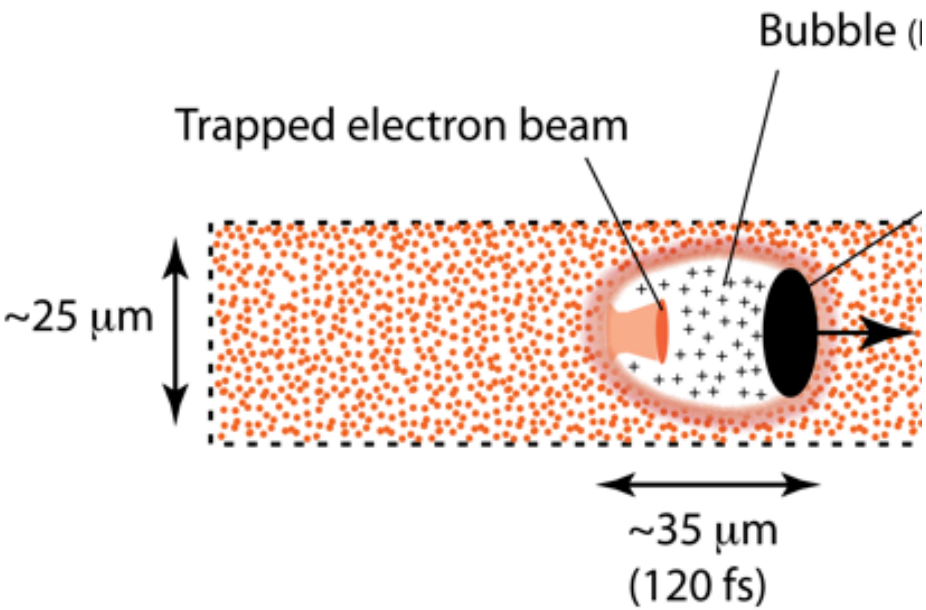


Reminder: Plasma-Acceleration (Internal Injection)



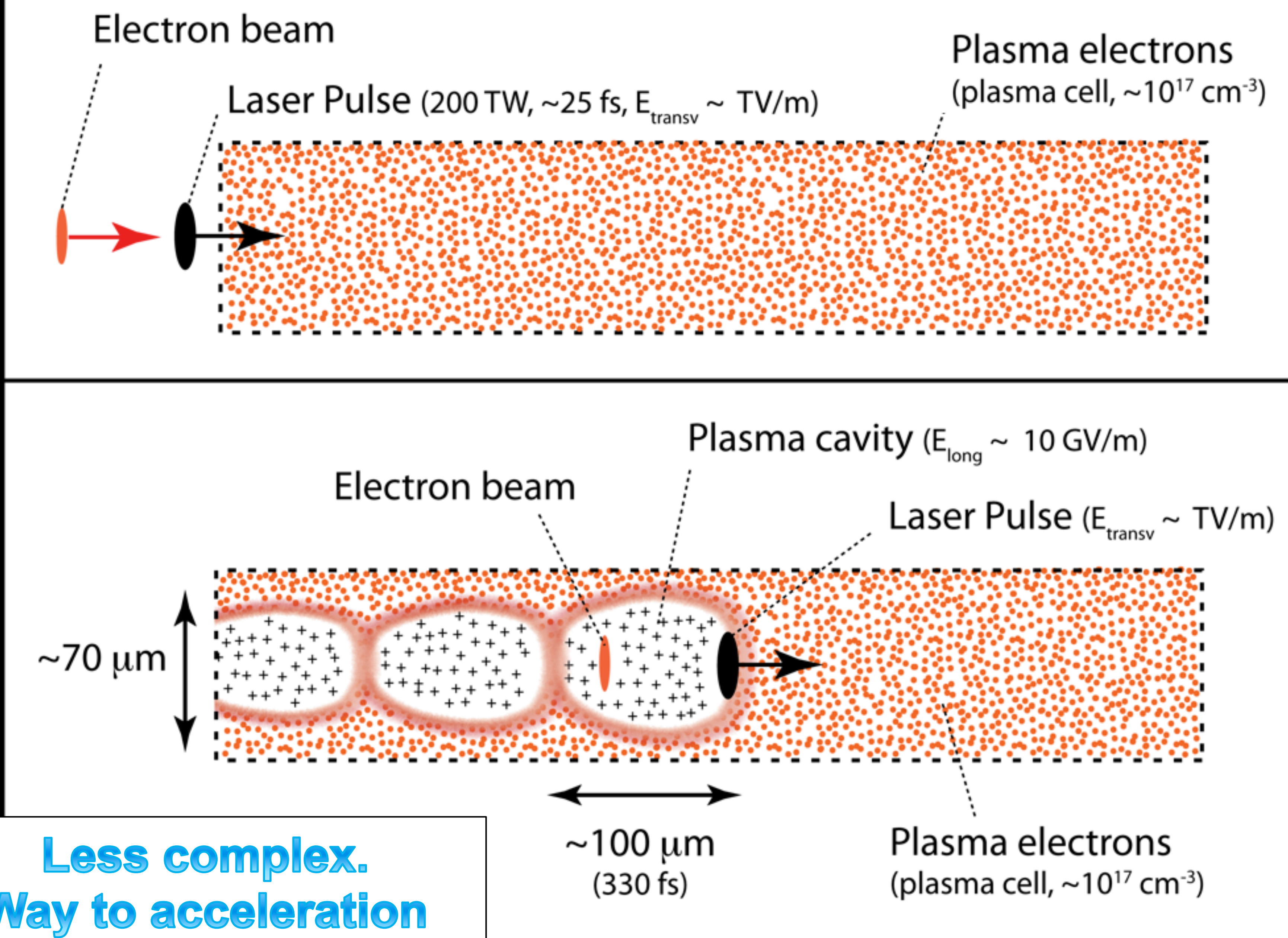
This accelerator fits into a human hair!

Reminder: Plasma-Acceleration (Internal Injection)



- This proved highly successful with electron bunches of **up to 4.25 GeV produced over a few cm**.
- Small dimensions involved → few **micron tolerances**!
- Highly compact but also **highly complex** accelerator: generation, bunching, focusing, acceleration, (wiggling) all in one small volume.
- Energy spread and stability at the few % level.

External Injection…



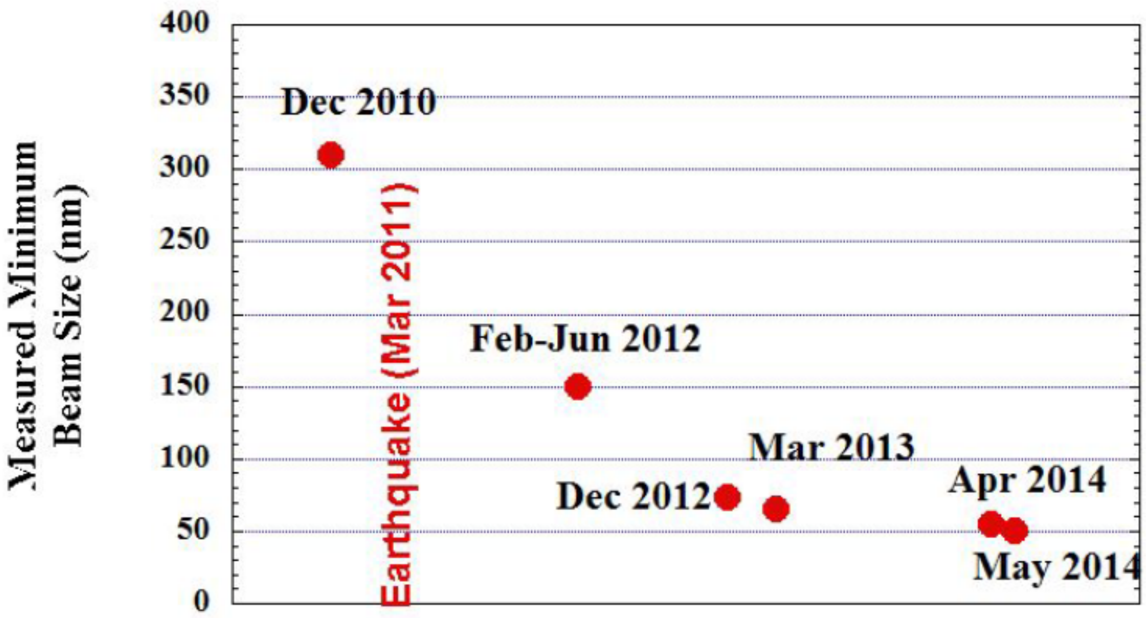
Less complex.
Way to acceleration stages.

Accelerator Builder's Challenge *(simplified to typical values)*

- Match into and out of plasma with **beam size around 1 µm** (about 1 mm beta function).
- Control **offsets** between the wakefield driver (laser or beam) and the accelerated electron bunch at **1 µm level**.
- Use **short bunches (few fs)** to minimize energy spread.
- Achieve **synchronization stability of few fs** from injected electron bunch to wakefield (energy stability and spread).
- Control the **charge and beam loading** to compensate energy spread (idea Simon van der Meer).
- Develop and demonstrate **user readiness of a 5 GeV plasma accelerated beam**.

Accelerator Builder's Challenge – Feasible?

> Difficult but we believe solutions can be found. Will not come for free…



50 nm with a 1.3 GeV electron beam
(from K. Kubo et al. Proc. IPAC 2014)

Accelerator Builder’s Challenge – Feasible?

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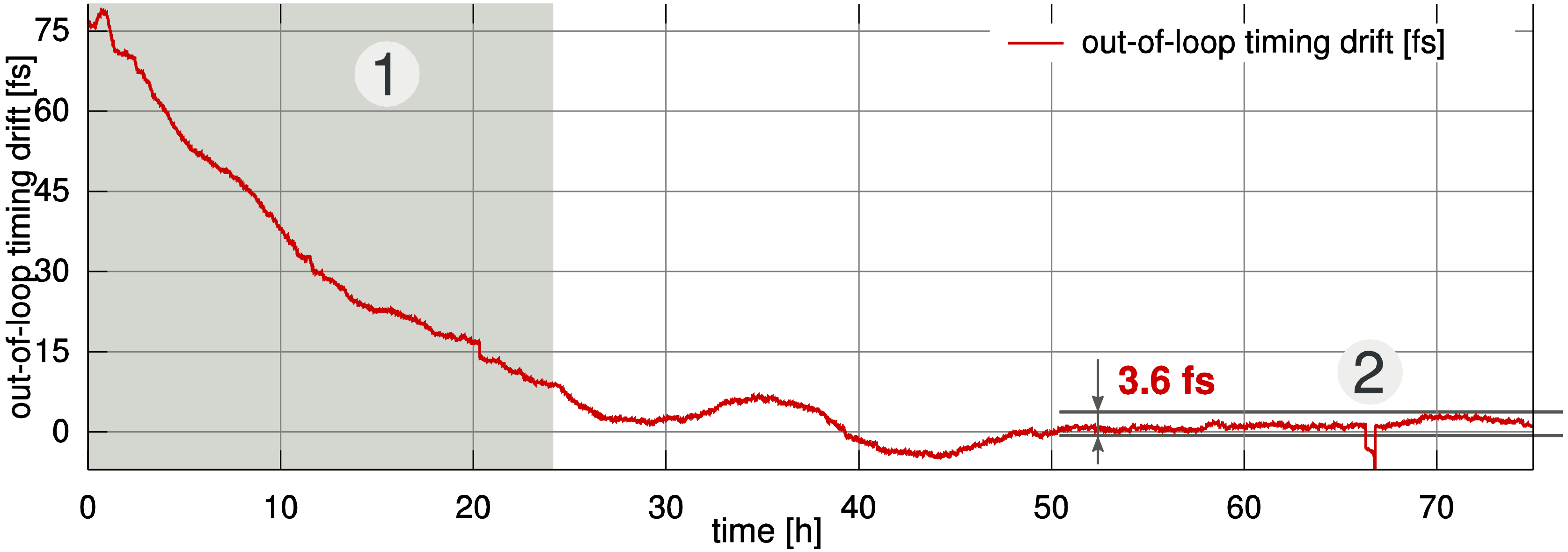

Femtosecond Precision in Laser-to-RF Phase Detection

(from H. Schlarb, T. Lamb, E. Janas et al. Report on DESY Highlights 2013).

> Again: **No fundamental limit here, but strong technical challenges!**

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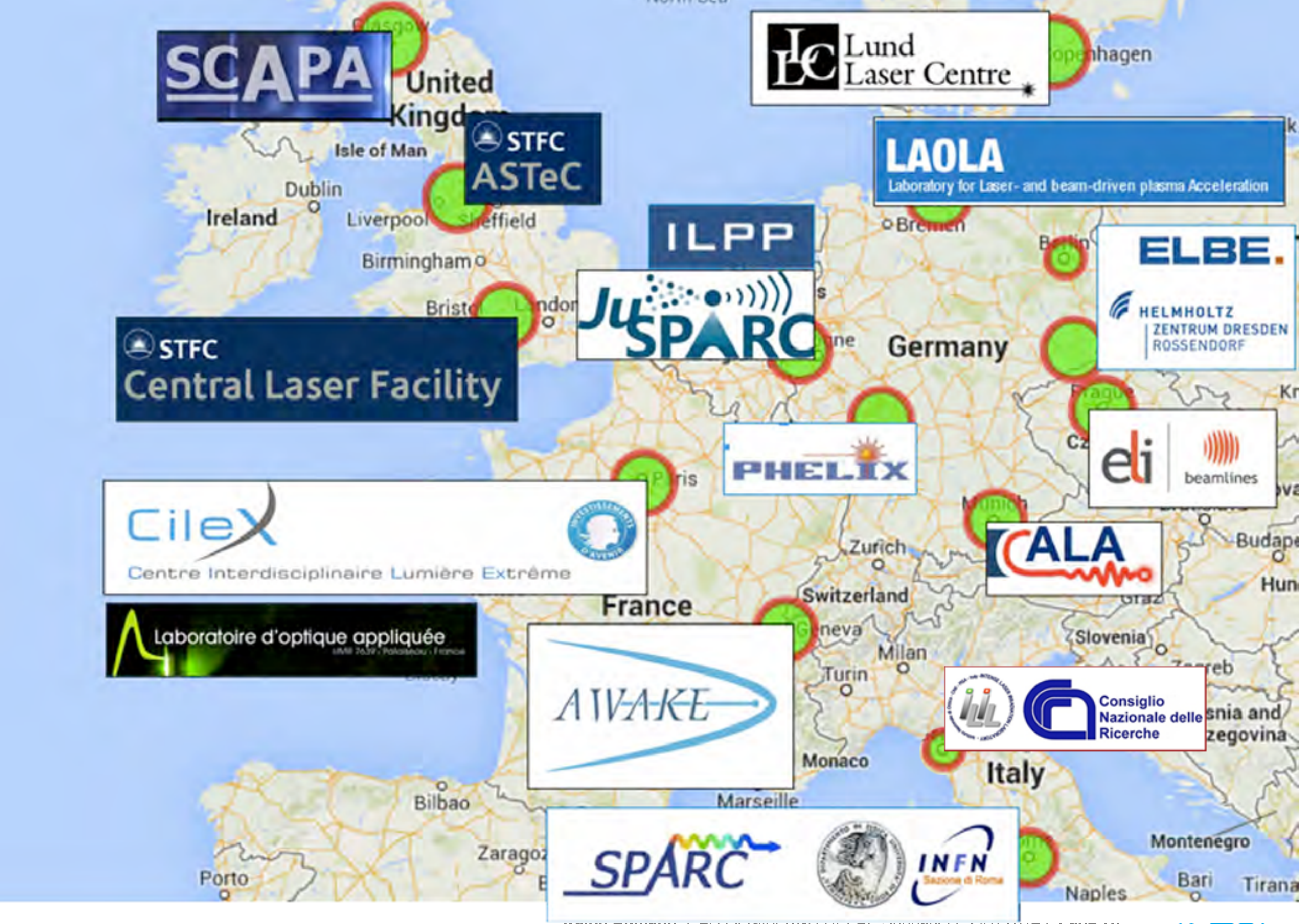
Status in Europe

- Quite a number of national investments in the EU member states at the 10 – 50 M€ level.
  - Europe is very competitive: excellent lasers, large expertise, big teams with many young students/researchers, new ideas from Europe have leading influence.
  - E.g. invention of “bubble regime” in Europe:

Pukhov, Alexancer, and Jürgen Meyer-ter-Vehn. "Laser wake field acceleration: the highly non-linear broken-wave regime." Applied Physics B 74.4-5 (2002): 355-361.

736 citations



SCAPA
United
STFC
ASTeC
Isle of Man
Dublin
Ireland
Liverpool
Birmingham
STFC
Central Laser Facility
Lund
Laser Centre
LAOLA
Laboratory for Laser- and beam-driven plasma Acceleration
ILPP
JuSPARC
Germany
ELBE.
HELMHOLTZ
ZENTRUM DRESDEN
ROSSENDORF
eli
beamlines
PHELIX
CALA
CileX
Centre Interdisciplinaire Lumière Extrême
Laboratoire d'optique appliquée
France
Zurich
Switzerland
Milan
Turin
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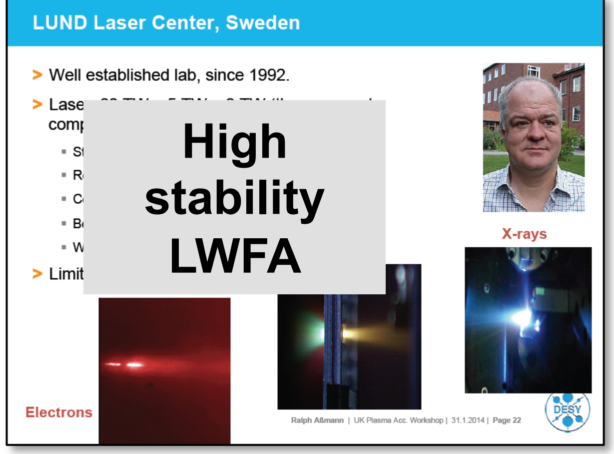
AWAKE
Consiglio
Nazionale delle
Ricerche
Monaco
Italy
Bilbao
Marseille
Porto
SPARC
INFN
Montenegro
Bari
Naples


CILEX Project, Plateau de Saclay, France
The big French project.
5 PW laser and LWFA area
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 17
DESY


LUND Laser Center, Sweden
Well established lab, since 1992.
High stability LWFA
X-rays
Electrons
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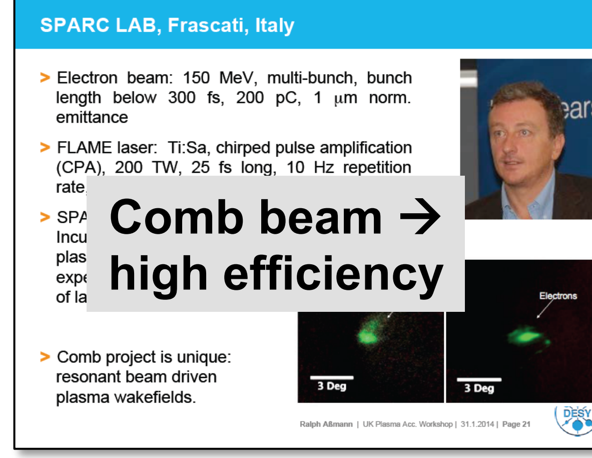
SPARC LAB, Frascati, Italy
Electron beam: 150 MeV, multi-bunch, bunch length below 300 fs, 200 pC, 1 µm norm. emittance
FLAME laser: Ti:Sa, chirped pulse amplification (CPA), 200 TW, 25 fs long, 10 Hz repetition rate.
Comb beam → high efficiency
Comb project is unique: resonant beam driven plasma wakefields.
Electrons
3 Deg
3 Deg
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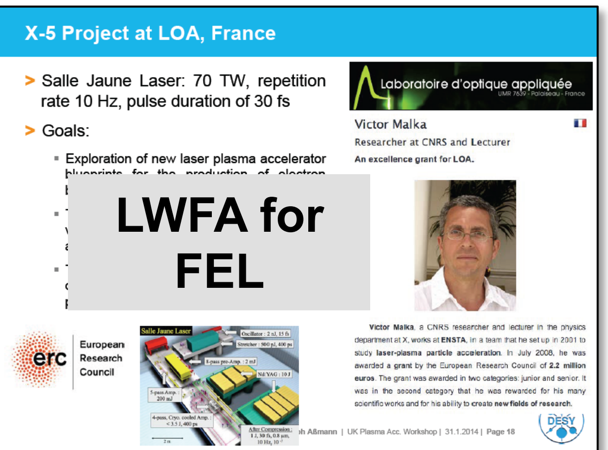
X-5 Project at LOA, France
Salle Jaune Laser: 70 TW, repetition rate 10 Hz, pulse duration of 30 fs
Goals:
Exploration of new laser plasma accelerator
LWFA for FEL
Laboratoire d'optique appliquée
Victor Malka
Researcher at CNRS and Lecturer
An excellence grant for LOA.
Victor Malka, a CNRS researcher and lecturer in the physics department at X, works at ENSTA, in a team that he set up in 2001 to study laser-plasma particle acceleration. In July 2008, he was awarded a grant by the European Research Council of 2.2 million euros. The grant was awarded in two categories: junior and senior. It was in the second category that he was rewarded for his many scientific works and for his ability to create new fields of research.
erc European Research Council
Salle Jaune Laser
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 18
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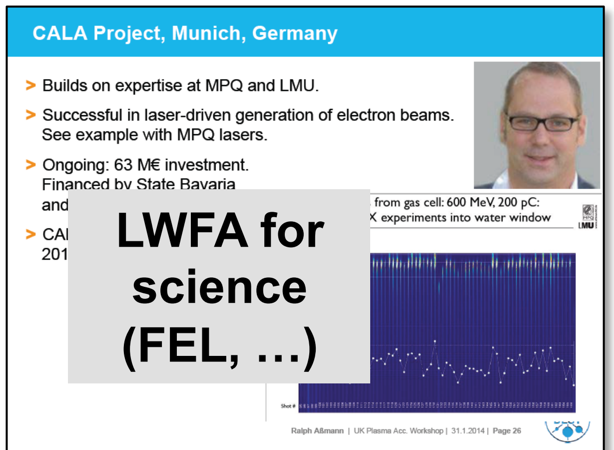
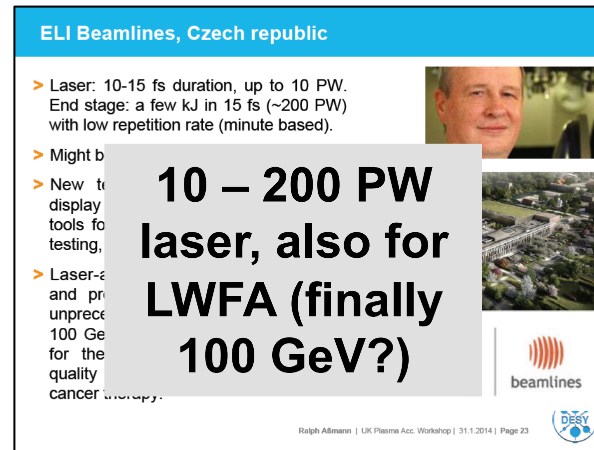

CALA Project, Munich, Germany
Builds on expertise at MPQ and LMU.
Successful in laser-driven generation of electron beams. See example with MPQ lasers.
Ongoing: 63 M€ investment.
Financed by State Bavaria
LWFA for science (FEL, …)
from gas cell: 600 MeV, 200 pC:
X experiments into water window
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 26


ELI Beamlines, Czech republic
Laser: 10-15 fs duration, up to 10 PW. End stage: a few kJ in 15 fs (~200 PW) with low repetition rate (minute based).
10 – 200 PW laser, also for LWFA (finally 100 GeV?)
beamlines
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 23
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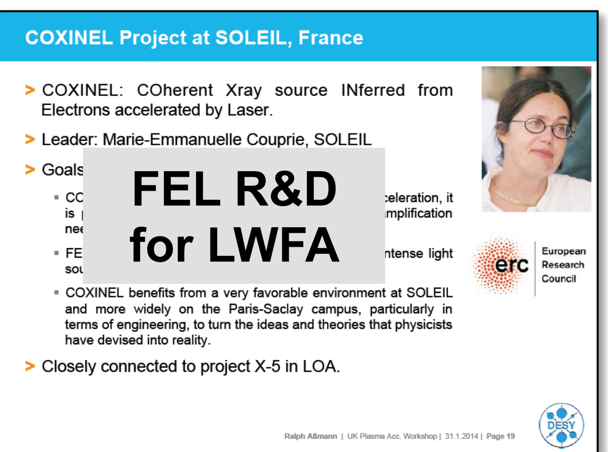
COXINEL Project at SOLEIL, France
COXINEL: COherent Xray source INferred from Electrons accelerated by Laser.
Leader: Marie-Emmanuelle Couprie, SOLEIL
Goals
FEL R&D for LWFA
COXINEL benefits from a very favorable environment at SOLEIL and more widely on the Paris-Saclay campus, particularly in terms of engineering, to turn the ideas and theories that physicists have devised into reality.
Closely connected to project X-5 in LOA.
erc European Research Council
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 19
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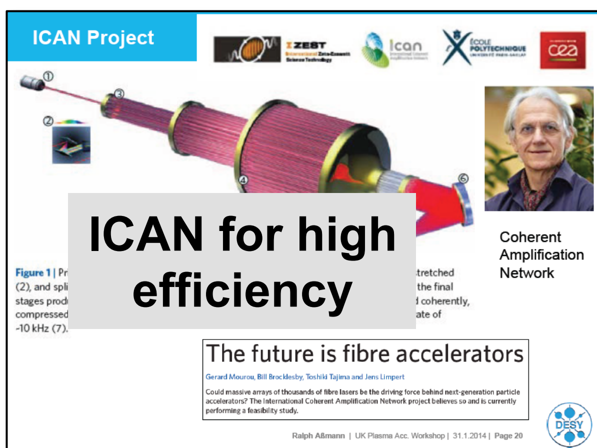
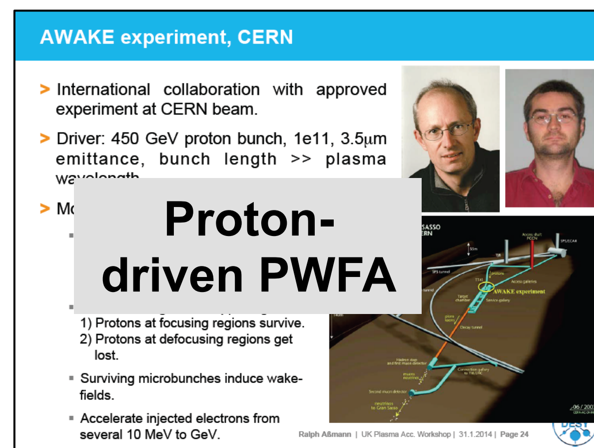
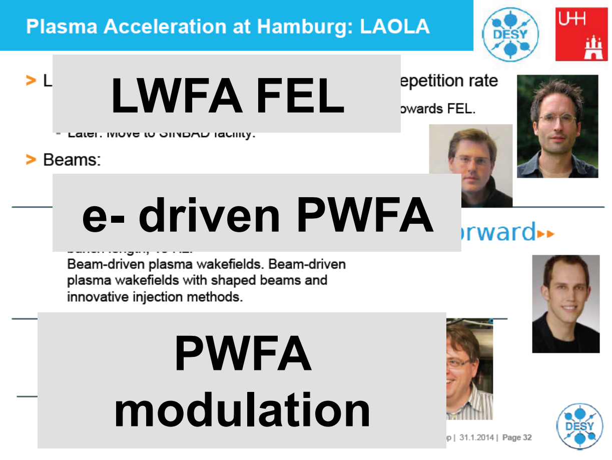

ICAN Project
ICAN for high efficiency
Coherent Amplification Network
The future is fibre accelerators
Gerard Mourou, Bill Brocklesby, Toshiki Tajima and Jens Limpert
Could massive arrays of thousands of fibre lasers be the driving force behind next-generation particle accelerators? The International Coherent Amplification Network project believes so and is currently performing a feasibility study.
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 20
DESY

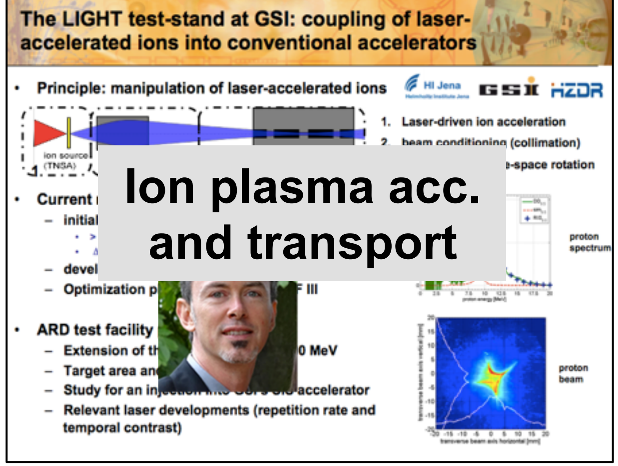

AWAKE experiment, CERN
International collaboration with approved experiment at CERN beam.
Driver: 450 GeV proton bunch, 1e11, 3.5µm emittance, bunch length >> plasma
Proton-driven PWFA
1) Protons at focusing regions survive.
2) Protons at defocusing regions get lost.
Surviving microbunches induce wake-fields.
Accelerate injected electrons from several 10 MeV to GeV.
Ralph Aßmann | UK Plasma Acc. Workshop | 31.1.2014 | Page 24



LWFA FEL

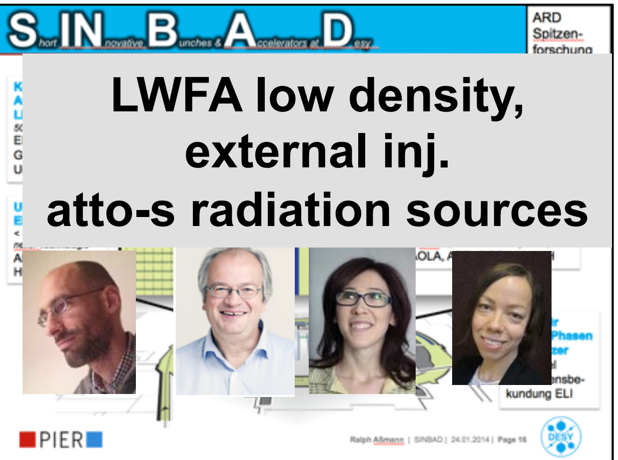
e- driven PWFA

PWFA modulation

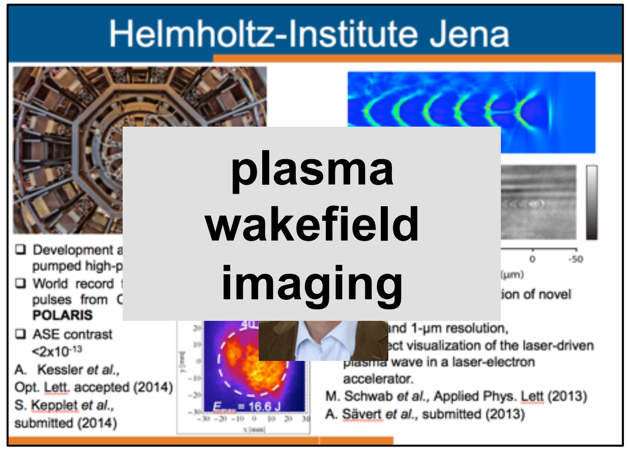


Ion plasma acc. and transport

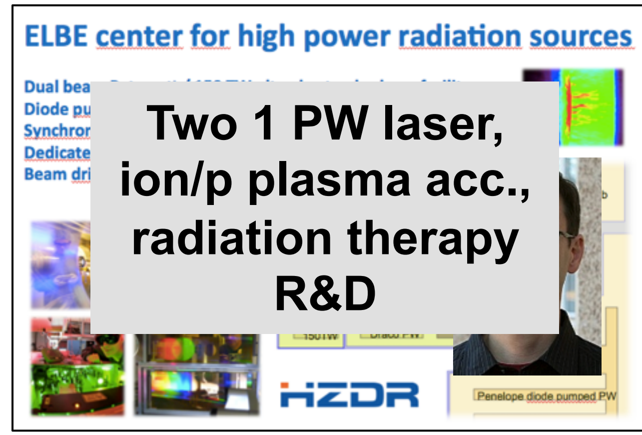
FEL, industrial applications, PWFA



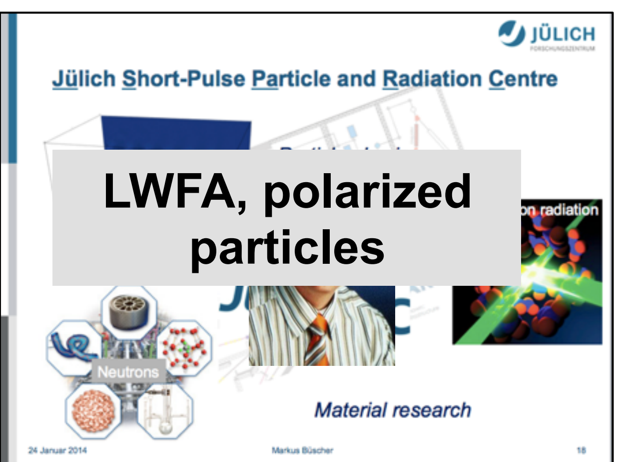
LWFA low density, external inj. atto-s radiation sources



plasma wakefield imaging

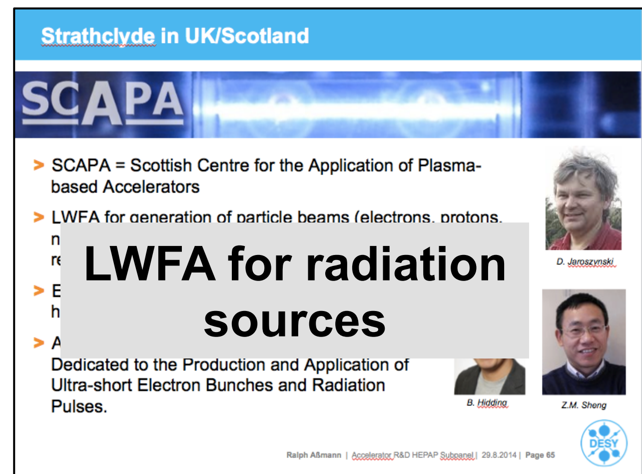


Two 1 PW laser, ion/p plasma acc., radiation therapy R&D



LWFA, polarized particles

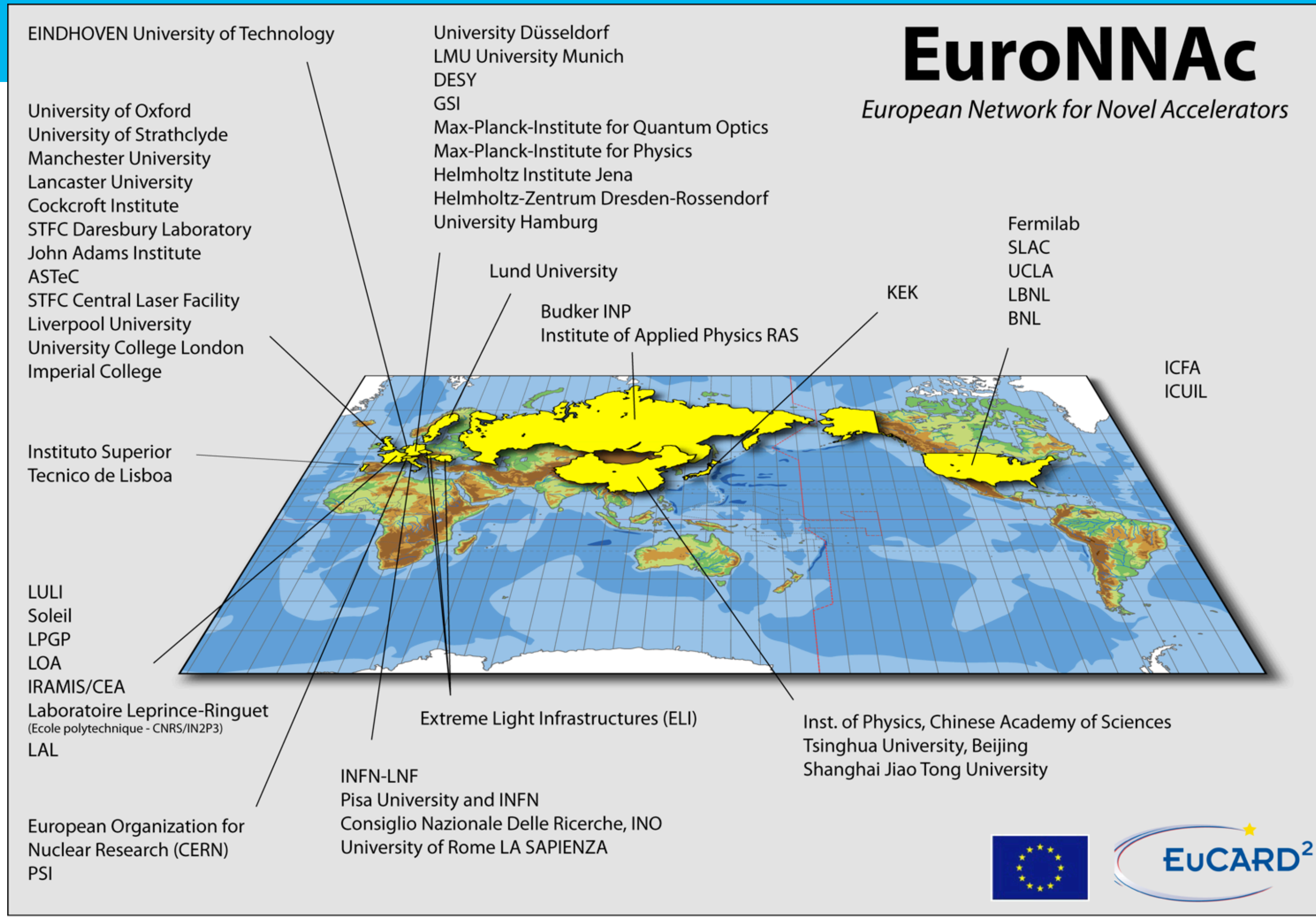
LWFA, medical imaging, training



LWFA for radiation sources

EU Funded Network on Novel Accelerators

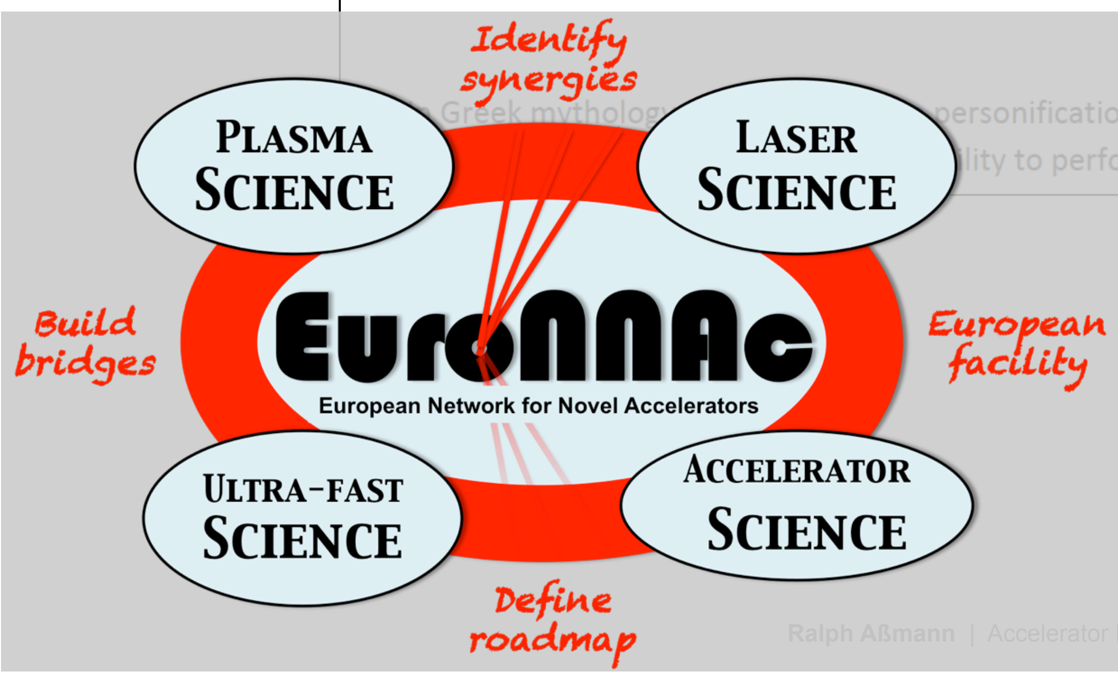
1st European Advanced Accelerator Workshop EAAC2013



The EuPRAXIA Project Proposal

Proposal for a H2020 Design Study "European Plasma Research Accelerator with eXcellence In Applications" (EuPRAXIA*)

Collaborative Project



*...n Greek mytholog... personification of well-being. In medicine the term Eupraxia ...ility to perform coordinated movements.

EuPRAXIA – Connected Labs and Institutes

List of participants:

Participant no.	Participant organisation name	Short name	Country
1 (Coordinator)	Stiftung Deutsches Elektronen Synchrotron	DESY	Germany
2	Istituto Nazionale di Fisica Nucleare	INFN	Italy
3	Consiglio Nazionale delle Ricerche	CNR	Italy
4	Centre National de la Recherche Scientifique	CNRS	France
5	University of Strathclyde	USTRAH	UK
6	Instituto Superior Técnico	IST	Portugal
7	Science & Technology Facilities Council	STFC	UK
8	Synchrotron SOLEIL – French National Synchrotron	SOLEIL	France
9	University of Manchester	UMAN	UK
10	University of Liverpool	ULIV	UK
11	Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenible	ENEA	Italy
12	Commissariat à l'Énergie Atomique et aux énergies alternatives	CEA	France
13	Sapienza Universita di Roma	UROM	Italy
14	Universität Hansestadt Hamburg	UHH	Germany
15	University of Oxford	UOXF	UK
16	Imperial College London	ICL	UK

16 beneficiaries from 5 EU member states

plus 18 associated partners

Associated partner organisation name	Short name	Country
Jiaotong-Universität Shanghai	JUS	China
Tsingua University Beijing	TUB	China
Extreme Light Infrastructures - Beams	ELI-B	Czech Repu
Lille University	PHLAM	France
Helmholtz Institute Jena	HIJ	Germany
Helmholtz-Zentrum Dresden-Rossendorf	HZDR	Germany
Ludwig-Maximillians-Universität München	LMU	Germany
Wigner Research Center of the Hungarian Academy of Science	WIGNER	Hungary
European Organization for Nuclear Research	CERN	IEIO[1]
High Energy Accelerator Research Organization	KEK	Japan
Kansai Photon Science Institute, Japan Atomic Energy Agency	KPSI-JAEA	Japan
Osaka University	OU	Japan
RIKEN SPring-8 Center	RSC	Japan
Lund University	LU	Sweden
Center for Accelerator Science and Education at Stony Brook U & BNL	CASE	USA
Lawrence Berkeley National Laboratory	LBNL	USA
SLAC National Accelerator Laboratory	SLAC	USA
University of California, Los Angeles	UCLA	USA

EuPRAXIA – Support

European Steering Group for
Accelerator R&D, 2014

EuPRAXIA

Producing high acceleration gradients is a critical issue for particle accelerators, as highlighted by the European Strategy for Particle Physics. The feasibility of large acceleration gradient (up to 100 GV/m) within exited plasma channels is demonstrated since several decades. More recently, it has been shown that appropriate beam properties (low emittance and beam energy dispersion as well as acceptable bunch charge) can be obtained. Europe is at the forefront of this research. Based on these achievements, the realization of accelerators with appropriate beam characteristics for user-communities is now credible and highly desirable.

The vast majority of accelerators operating in the world are relatively low energy (<~10 GeV) facilities including light sources, medical and industrial applications. However these infrastructures remain complex to develop and operate and necessitate relatively large footprints.

The EuPRAXIA proposal aims at establishing the design of a 1 to 5 GeV electron accelerator with pilot applications for the Free Electron Laser user community as well as the community developing state-of-the-art particle detectors.

The proposal is technically strong and federates the major European competences and institutes required to accomplish the needed tasks.

"… the realization of accelerators with appropriate beam characteristics for user-communities is now credible and highly desirable."

competition from CERN FCC and
ESS neutrino upgrade DS proposals

THALES

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To whom it may concern

N° de certificat 351057

Date: 05/08/2014

Réf. /TOSA/DSL/05/08/2014

Objet / *Subject*: EuPRAXIA

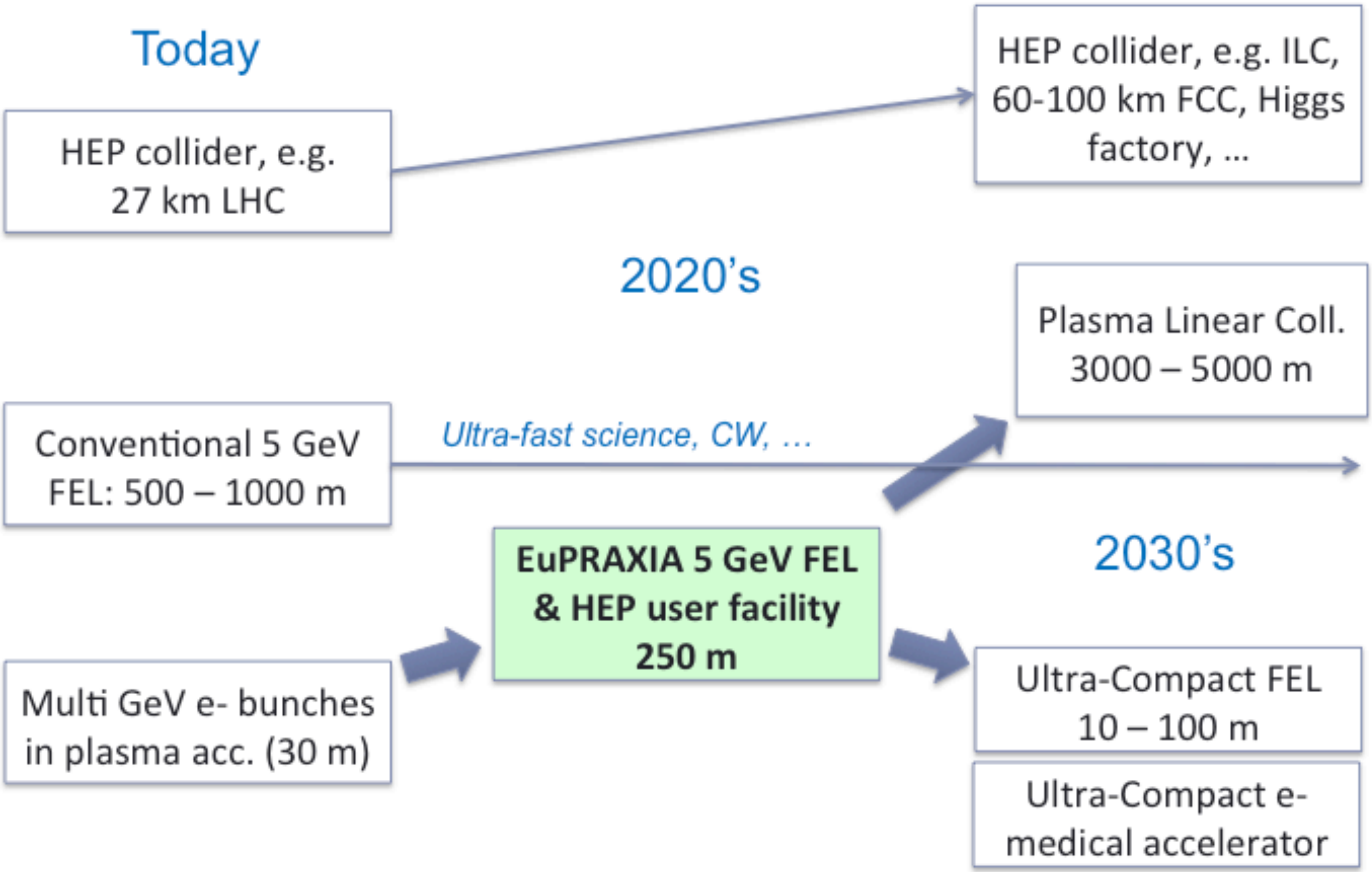
Madame, Sir,

We have been informed by Mr François MATHIEU, Project Manager of APOLLON program at CNRS, about the EuPRAXIA proposal of Design Study for a Large Research Infrastructure based on laser-plasma acceleration.
Thales Optronique is recognized as leader of Intense Laser System for particles acceleration. In 2012, Thales Optronique has successfully installed at Berkeley the first commercial PetaWatt laser System for the BELLA project of US Department of Energy which is using the same physics concepts. In 2013, Thales Optronique installed a second PetaWatt laser system in Bucharest (Romania).
Thales is also involved in other large projects aiming to introduce the laser technology in the world of accelerators as it has been the case for a system now running at DESY in Germany and for another system in construction to be installed in Japan on the SACLA infrastructure involving a large free-electrons laser.
All these new projects exploit the specific advantages provided by the technology of laser-plasma acceleration and in particular the compactness inherent to the concept.
Therefore it is expected by the whole community of accelerators that these new machines will have also much better capabilities to developp societal applications like in medicine for cancer therapy and in industry for high resolution non-destructive inspection with X-rays or Gamma rays.
Therefore Thales Optronique is highly supportive of EuPRAXIA proposal for allowing European Union to be at the peak of this science and of related industry.

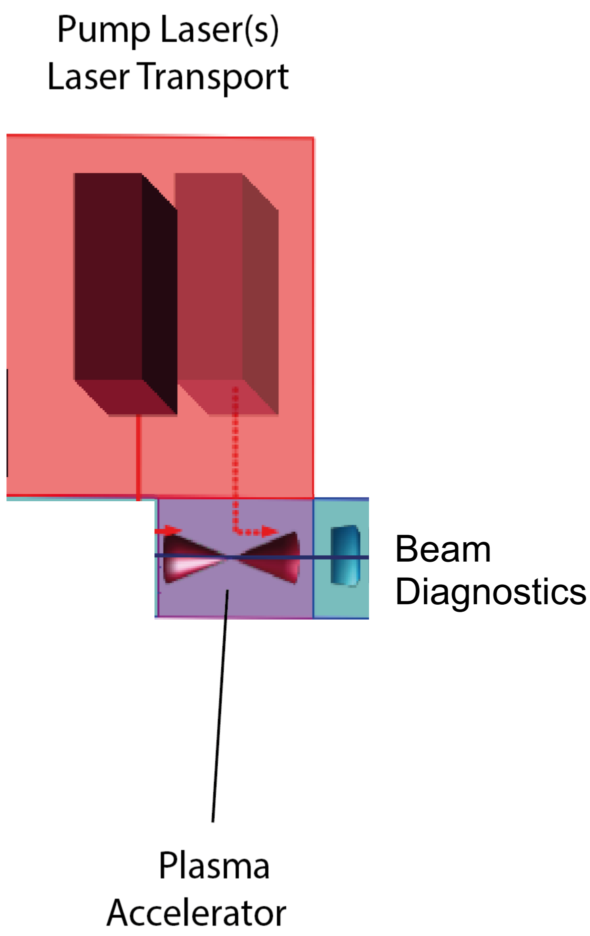
Sincerely yours,

Denis LEVAILLANT
Director of Laser Business Unit

Ansatz: Required Intermediate Step to Plasma LC



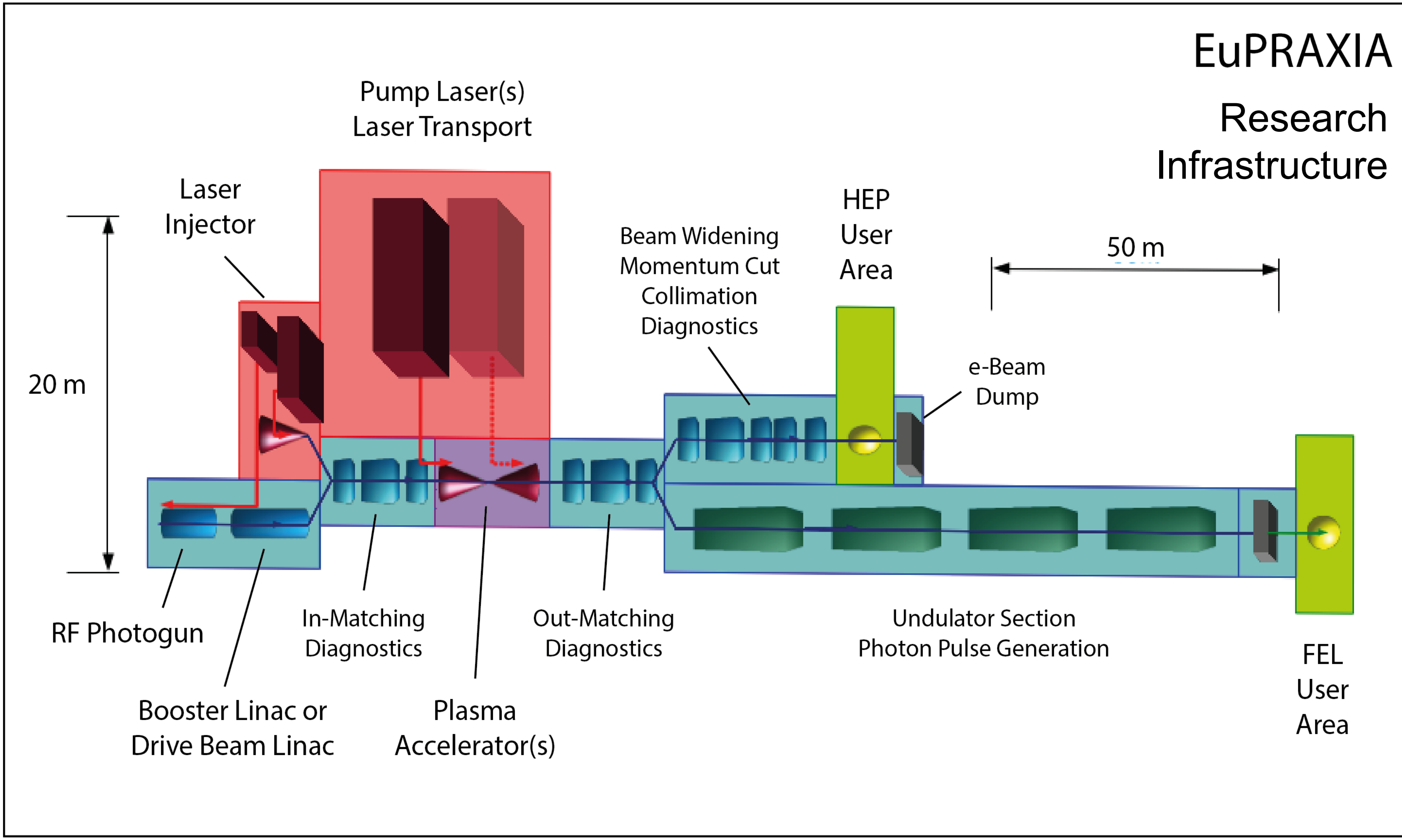
Schematic Layout EuPRAXIA Research Infrastructure



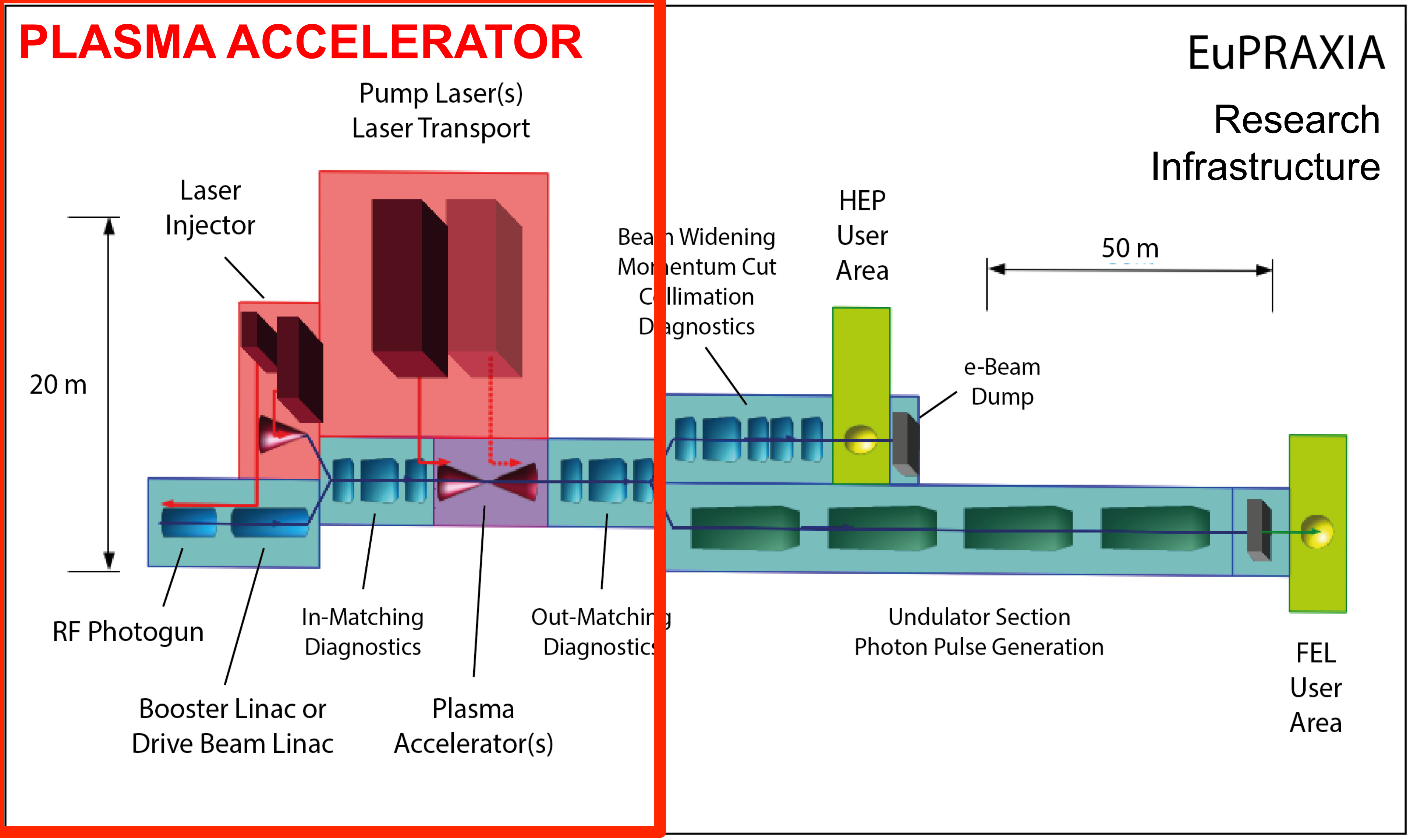
Present Laser Plasma Acce-lerators

Up to 4.25 GeV electron beams

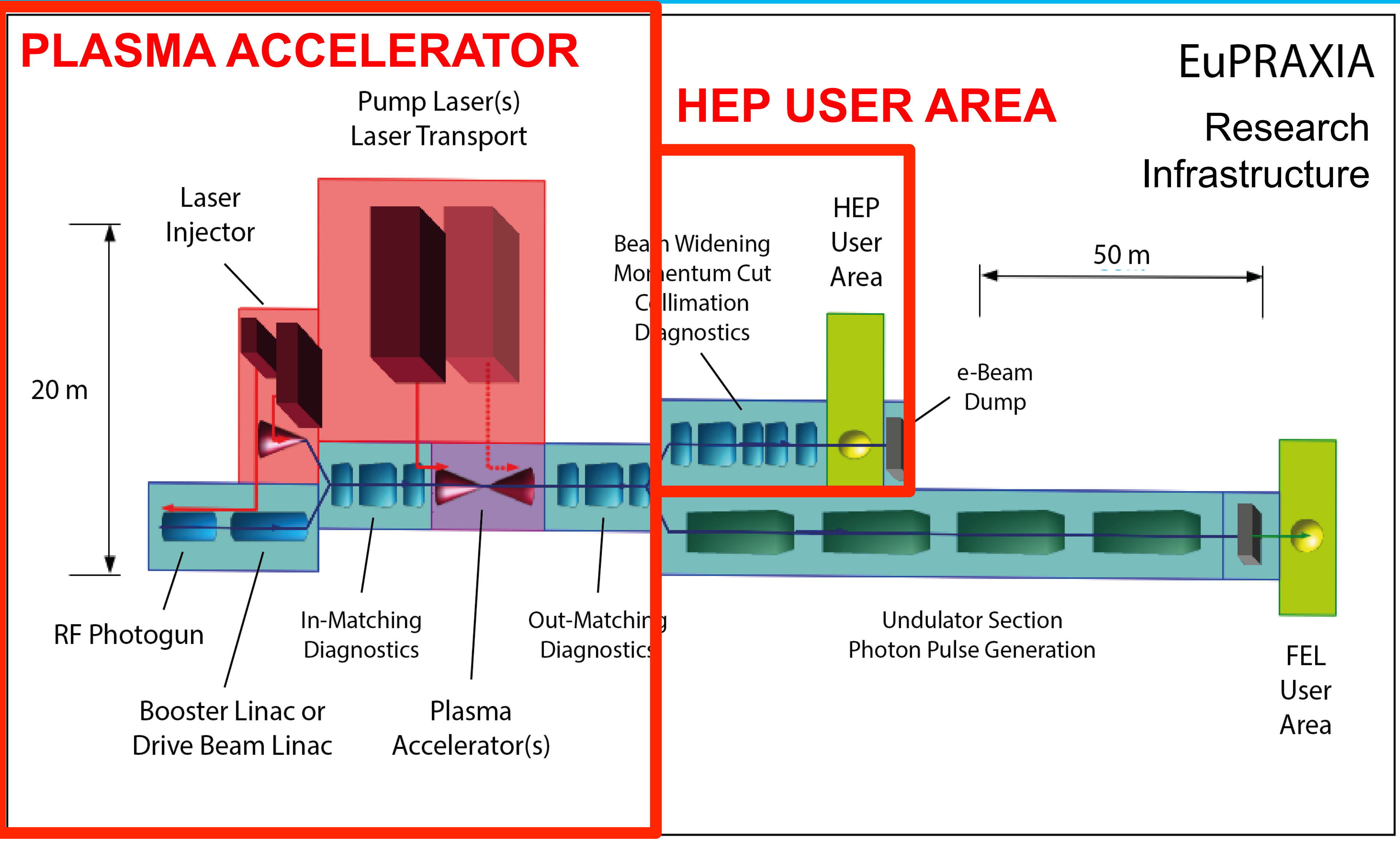
Schematic Layout EuPRAXIA Research Infrastructure



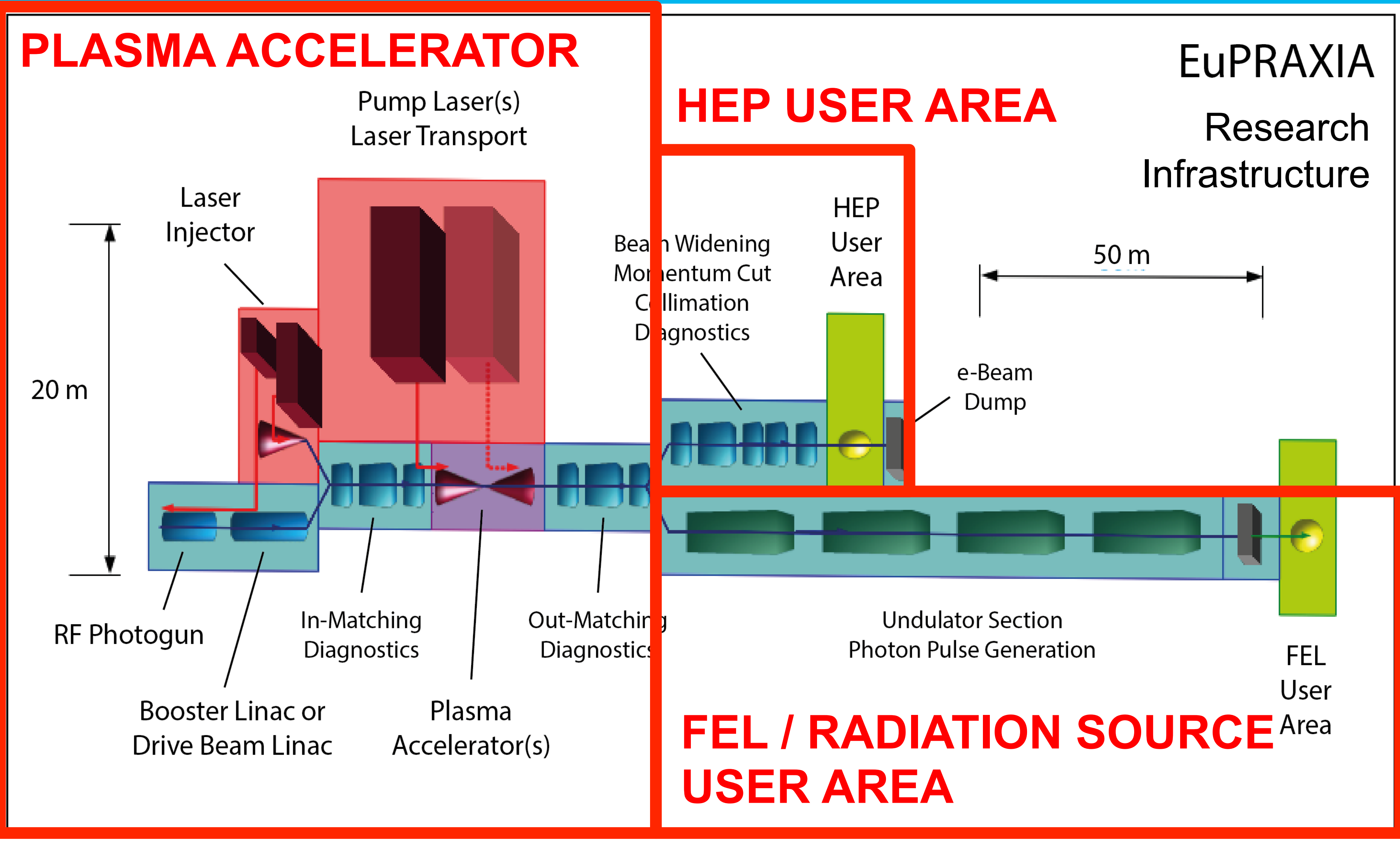
Schematic Layout EuPRAXIA Research Infrastructure



Schematic Layout EuPRAXIA Research Infrastructure



Schematic Layout EuPRAXIA Research Infrastructure



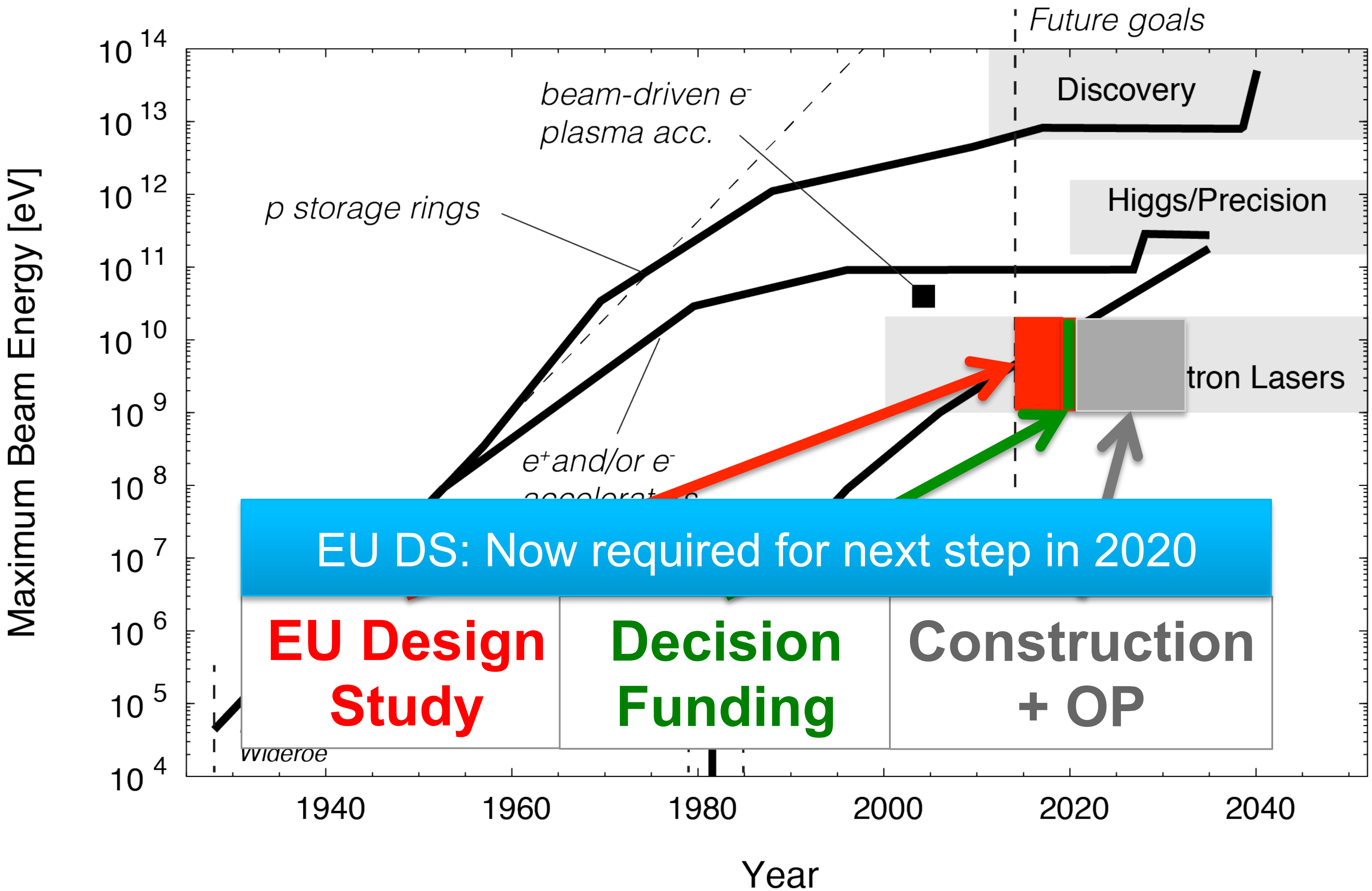
EuPRAXIA Research Infrastructure Goal Parameters

Beam Parameter	Unit	Value
Particle type	-	Electrons
Energy	GeV	1 – 5
Charge per bunch	pC	1 – 50
Repetition rate	Hz	10
Bunch duration	fs	0.01 - 10
Peak current	kA	1 – 100
Energy spread	%	0.1 – 5
Norm. emittance	mm	0.01 – 1

Envisaged Implementation

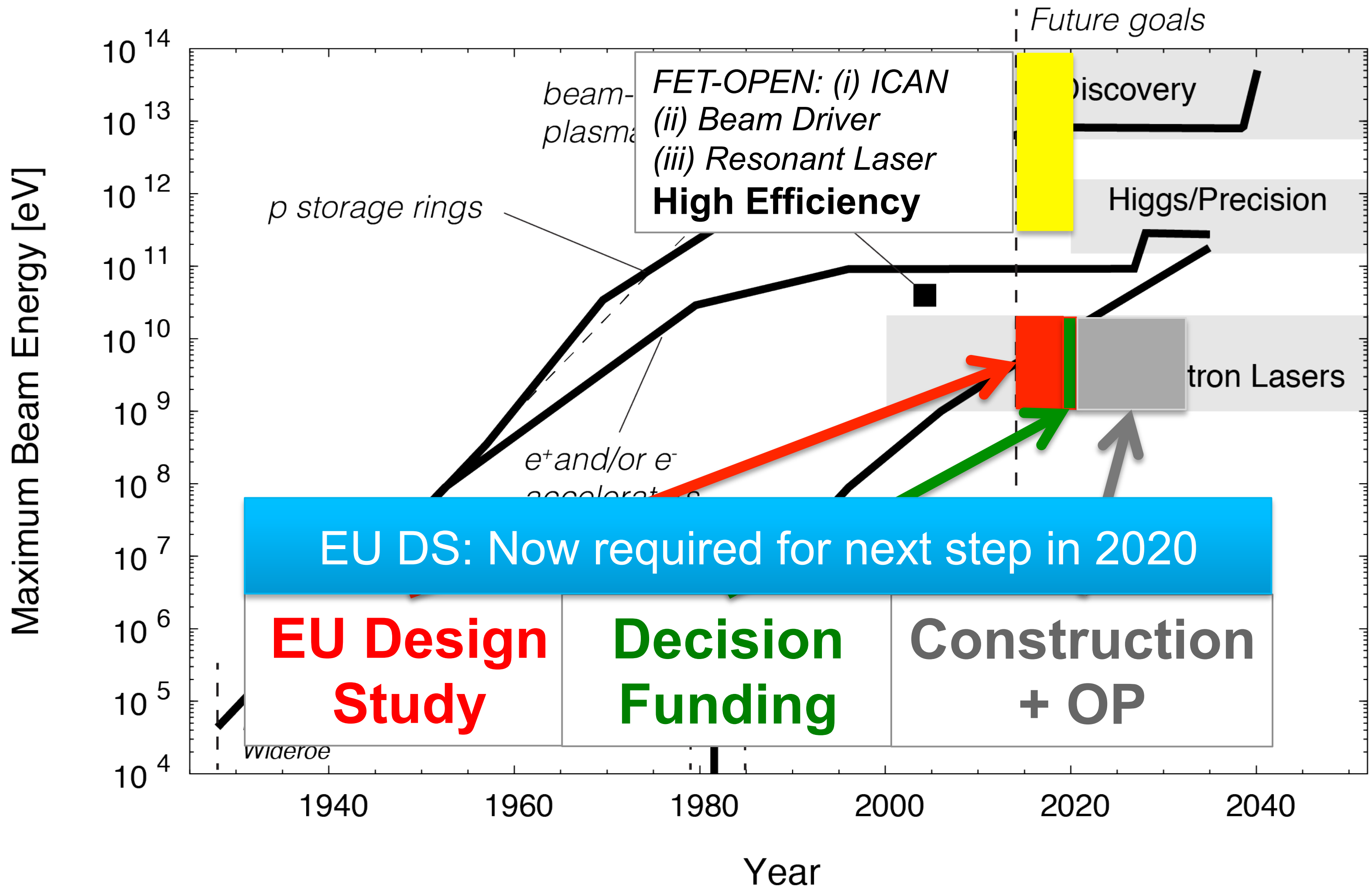
- Goal is to design one operational facility at one location.
- Resources will be distributed to all partners:
  - Model of big particle physics detector: Many institutes team up to build one detector at one place, each contributing a part.
- Site study with the goal to propose the best site:
  - Existing infrastructure, host lab support, scientific user community, support from funding agency, …
- Facility will be devoted to provide for pilot users:
  - Ultra-compact X-ray FEL
  - Ultra-compact GeV electron source for HEP detector development

Timelines



R. Assmann, EuroNNAc @ ICAN, 4/2014

Timelines



R. Assmann, EuroNNAc @ ICAN, 4/2014

Outline

- Accelerators at the Energy Frontier
- Accelerator Builder's Challenge
- EuPRAXIA – Proposal for a European Plasma Accelerator for Users
- **Helmholtz ARD Program**
- Conclusions

Research field Matter in the Helmholtz Association

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

JÜLICH
FORSCHUNGSZENTRUM

GSI

+ Helmholtz Institutes
Jena and Mainz

KIT
Karlsruher Institut für Technologie

DESY

Hamburg and Zeuthen

HZB Helmholtz Zentrum Berlin

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

since 2011

(Total Helmholtz: 18 centers, 6 research fields, ~3B€ yearly budget)

DESY

Research Field Matter: new programme structure

Matter and the Universe	From Matter to Materials and Life	Matter and Technologies
Fundamental Particles and Forces	In-House Research on the Structure, Dynamics and Function of Matter at Large Scale Faciltities	Accelerator Research and Development
Cosmic Matter in the Laboratory	Facility Topic: Research on Matter with Brilliant Light Sources	Detector Technologies and Systems
Matter and Radiation from the Universe	Facility Topic: Neutrons for Research on Condensed Matter	
	Facility Topic: Physics and Materials Science with Ion Beams	
	Facility Topic: Research at Highest Electromagnetic Fields	

LK II
„performance category II“
= user operation of large scale facilities

Evaluation for the programme oriented funding 2015 – 19 in the research field* Matter *was recently completed

Accelerator R&D Progamme

Implementation phase in Helmholtz since 2011

ARD team at the rehearsal for the PoF3-evaluation (HZDR, 25Feb 2014)

Centres:	Forschungszentrum Jülich GSI Helmholtzzentrum für Schwerionenforschung Helmholtz-Zentrum Berlin für Materialien und Energie Helmholtz-Zentrum Dresden-Rossendorf Karlsruher Institut für Technologie
Programme Speaker:	Ties Behnke (DESY)

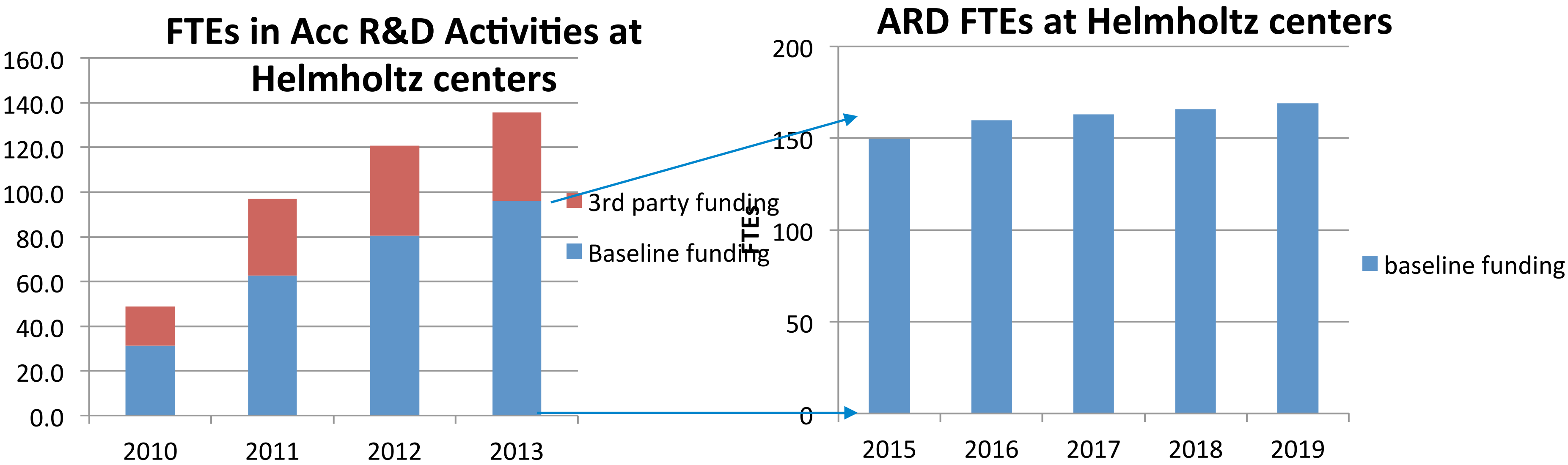
> Evaluation of Research Programme MT with topics ARD and DTS
> 26 - 28 March, 2014

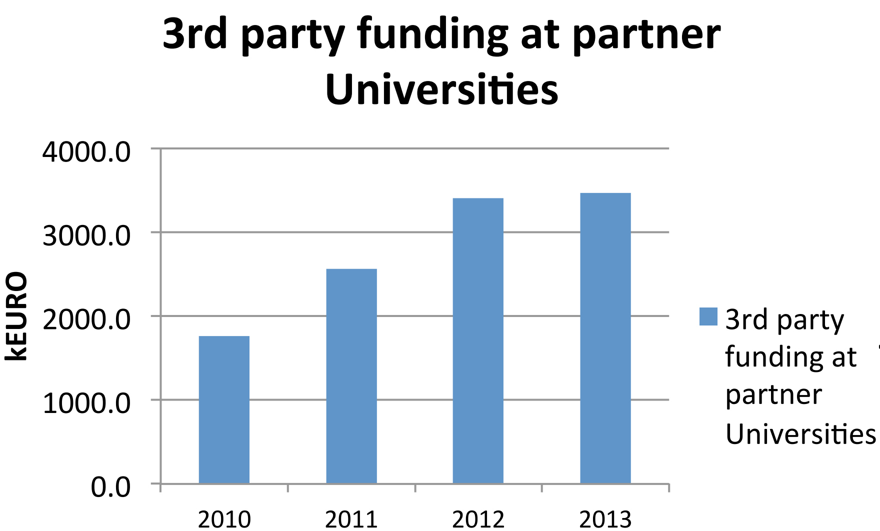
> Whole program and ARD in particular received excellent comments in oral close-out from evaluation committee

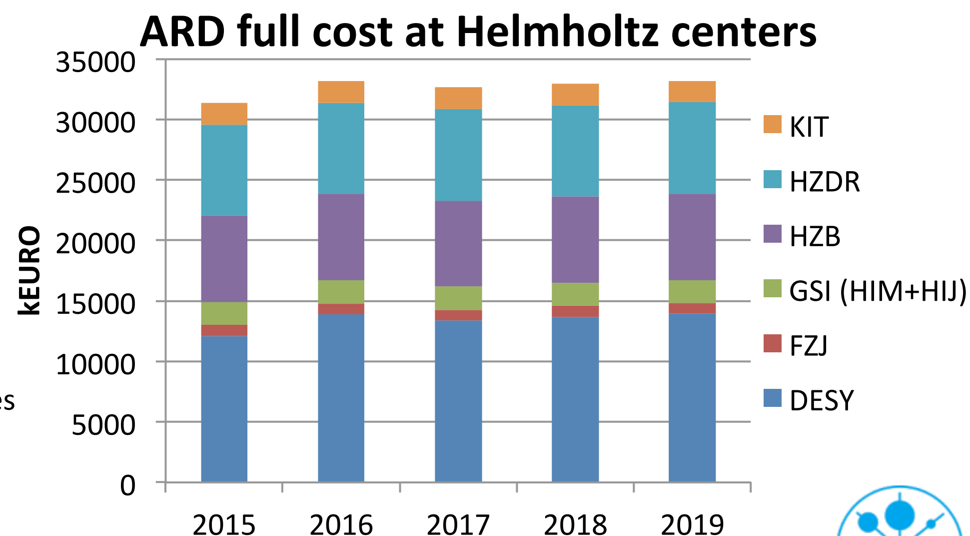
> Strategy with good balance between activities aiming at shorter term, direct impact on research infrastructures and more generic, visionary ones was especially praised

Past and future resources in accelerator R&D

(yearly increase from 2016 still to be decided)







ARD structure and coordination

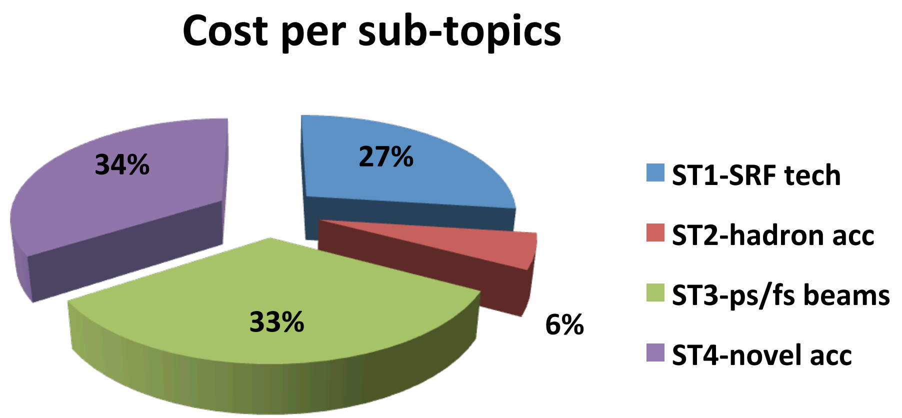
Topic 1: Accelerator Research and Development ARD

Speaker: R. Brinkmann/DESY, co-speaker: A. Jankowiak/HZB

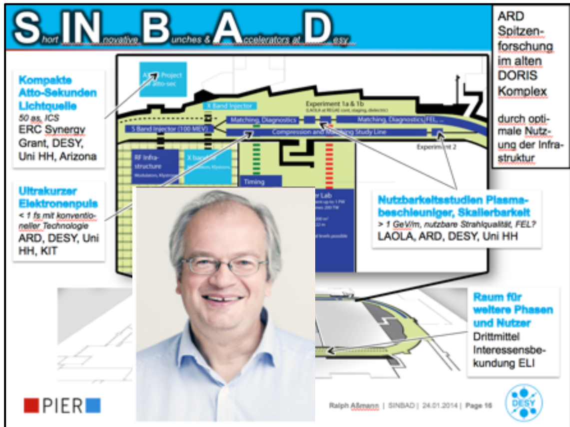
ST1: SRF science and technology	ST2: concepts & techn. for hadron acc.	ST3: ps – fs electron and photon beams	ST4: Novel acceleration concepts
Coordination: J. Knobloch/HZB, P. Michel/HZDR	Coordination: A. Lehrach/FZJ, P. Spiller/GSI	Coordination: H. Schlarb/DESY, A.-S. Müller/KIT	Coordination: U. Schramm/HZDR, F. Grüner/U-Hamburg

Networking, workshops, joint projects and usage of infrastructure, transfer of new technologies between centers

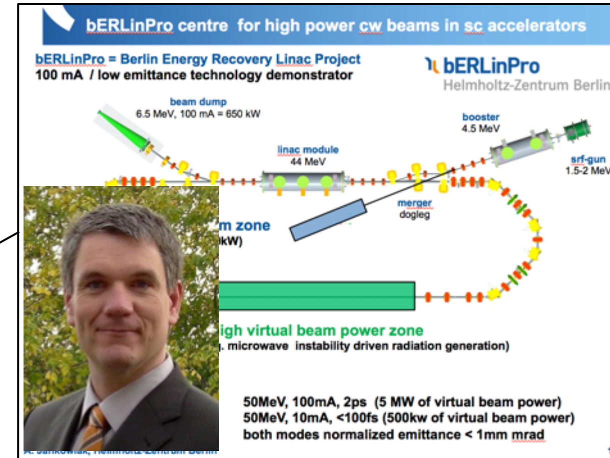
Cooperation with German universities, international partners and industry



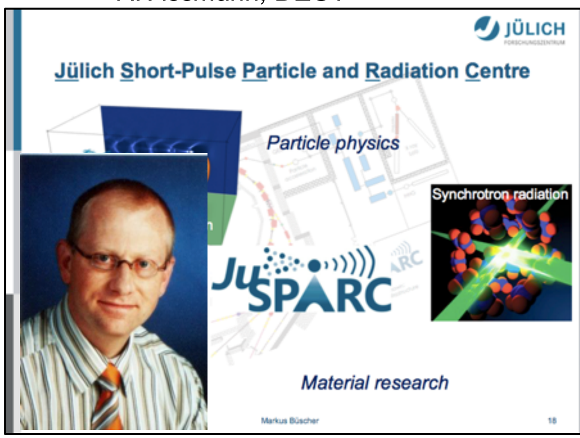
Coordination: Reinhard Brinkmann
Deputy: Andreas Jankowiak



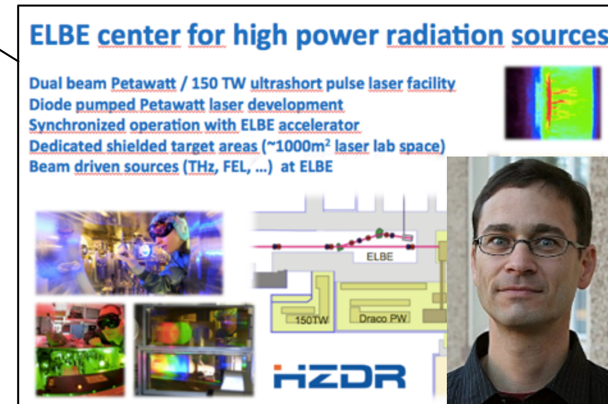
R. Assmann, DESY



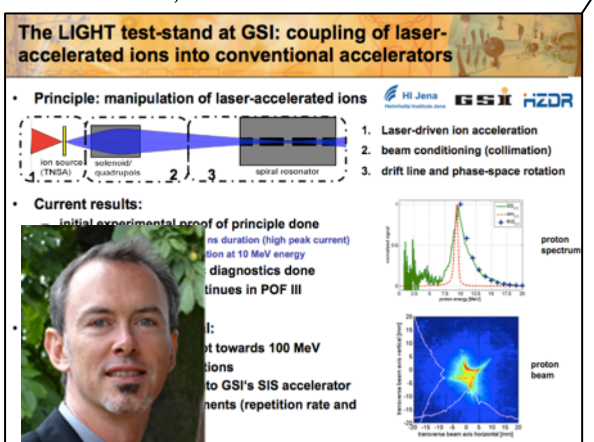
A. Jankoviak, HZB



M. Büscher, FZJ

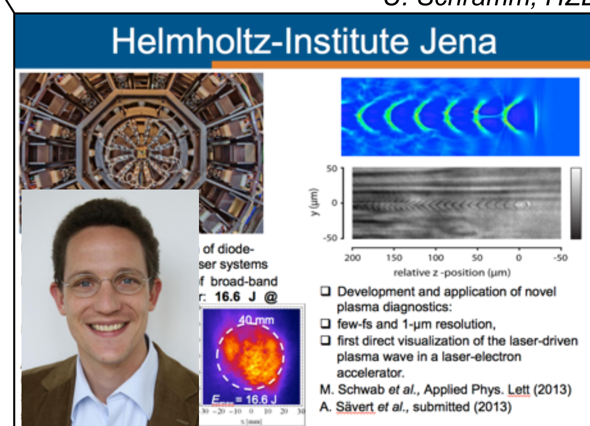


U. Schramm, HZDR



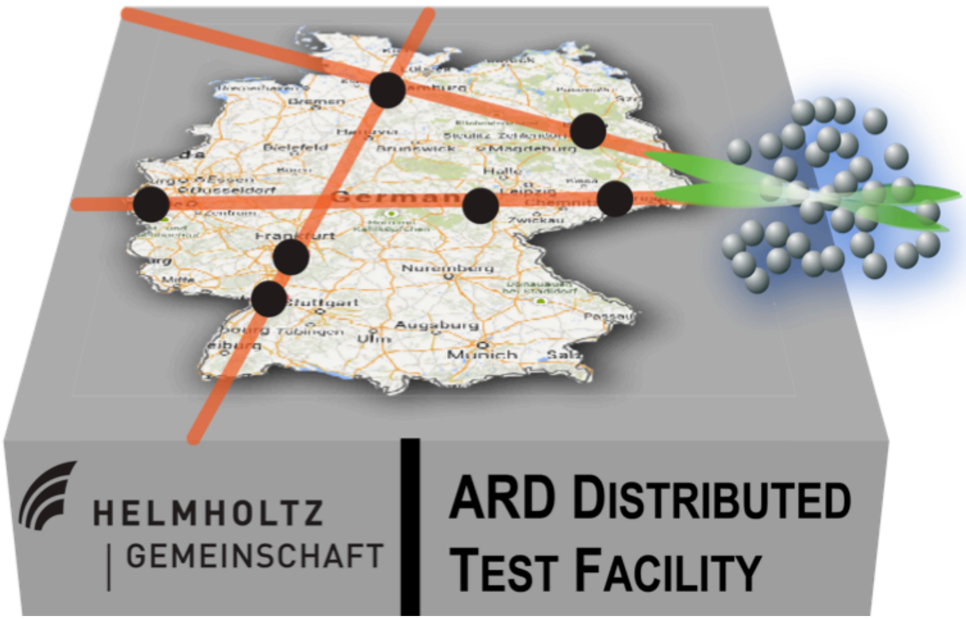
V. Bagnoud, GSI

A.S. Müller, KIT



M. Kaluza, HIJ

Proposal: Helmholtz Distributed ARD Test Facility – Germany



The preparation team:

R. Assmann (DESY), V. Bagnoud (GSI),
M. Büscher (HZJ), A. Jankowiak (HZB),
M. Kaluza (HIJ), A.-S. Müller (KIT),
U. Schramm (HZDR)

- Theme 1: **Collaboration**

  Networking of existing research infrastructure.

- Theme 2: **Synergy**

  Extension of facilities for common usage.

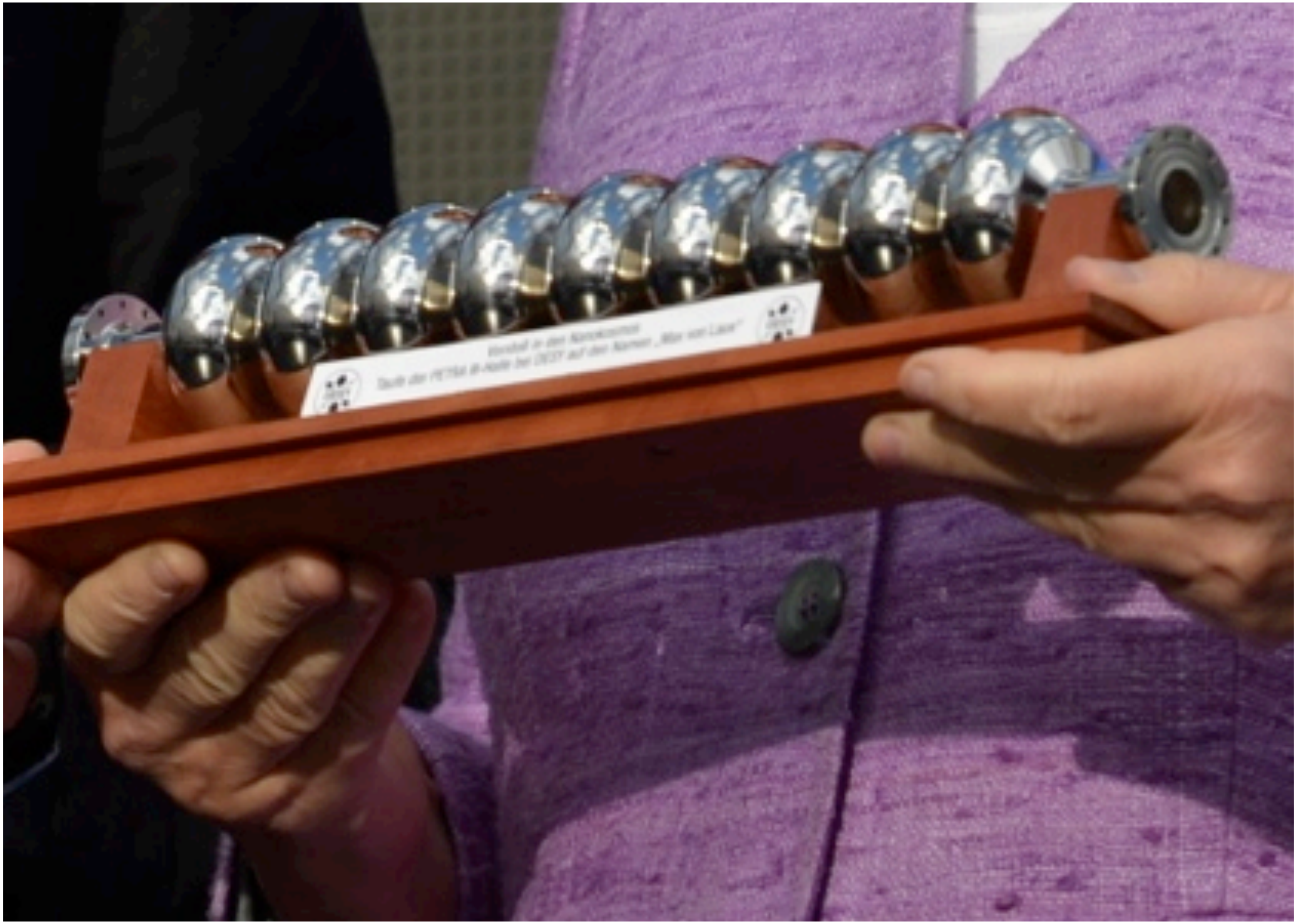
- Thema 3: **Leadership**

  2 flagship projects for internationally leading research with the **aim of ultra-compact accelerators and radiation sources** (plasma accele-ration major player).

Conclusions – General

- Conventional **accelerators are masterpieces of technology**, operating close to physical hard limits.
- New projects (plan A) **scale/extend existing technology** → excellent performance but **larger size and cost**.
- Many of us believe that a **plan B HEP project for the 2030's** is a good idea. Should be smaller and lower cost.
- Plasma accelerators **reduce acceleration lengths by factor 100 – 1000**. Excellent candidate plan B technology.
- Plasma accelerators: **potential for novel ultra-compact FEL's**, radiation sources, medical imaging (ultra-fast).
- Plasma accelerators not fundamentally limited. **Problems are difficult but of technical nature**.

Our mission: The compact accelerator for high power physicists!



… for high power physicists!

The size of the accelerator structure is correct, but we want to place a plasma accelerator structure there with 10 GeV acceleration!

Conclusions – Europe

- Europe: **Increased investments in novel accelerator R&D**. Accelerator R&D in Germany recognized as **independent research area**. Conventional and novel acc. R&D together. HEP and photon science acc. R&D together.
- Europe: **≈15 significant projects** in plasma acceleration. EuroNNAc: exchange info, develop common plans.
- Right time is now to spend time and efforts on **developing plasma accelerator technology to user readiness**.
- Efforts on **grouping our European efforts**: EuPRAXIA proposal, CILEX, Helmholtz Distributed ARD Test Facility, …
- We hope that our efforts will be flanked by **strengthened US efforts on accelerator R&D**. It will pay off for US science and for all of us.

Thank you for your attention…

CILEX Project, Plateau de Saclay, France

- The big French project.
- Laser: APOLLON, 150J / 15fs, 1 shot/min, 5-10 PW , 10^{23} W/cm^2 plus satellite lasers.
- 450 m^2 experimental area for plasma acceleration of e$^-$. Possibility to extend into 200m long acc. tunnel.

A. Specka

F. Amiranoff

X-5 Project at LOA, France

- Salle Jaune Laser: 70 TW, repetition rate 10 Hz, pulse duration of 30 fs
- Goals:
  - Exploration of new laser plasma accelerator blueprints for the production of electron beams and very strong peak point currents.
  - These electron beams will be used in a variety of domains, including life science and materials science.
  - They will also be used to study the blueprint of compact free electron lasers (FEL) for the production of intense X and XUV beams.

Laboratoire d'optique appliquée
UMR 7639 - Palaiseau - France

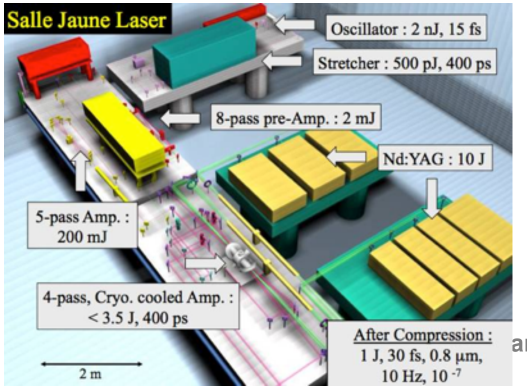
Victor Malka

Researcher at CNRS and Lecturer

An excellence grant for LOA.

Victor Malka, a CNRS researcher and lecturer in the physics department at X, works at **ENSTA**, in a team that he set up in 2001 to study **laser-plasma particle acceleration**. In July 2008, he was awarded a **grant** by the European Research Council of **2.2 million euros**. The grant was awarded in two categories: junior and senior. It was in the second category that he was rewarded for his many scientific works and for his ability to create **new fields of research**.

erc European Research Council



COXINEL Project at SOLEIL, France

- COXINEL: COherent Xray source INferred from Electrons accelerated by Laser.
- Leader: Marie-Emmanuelle Couprie, SOLEIL
- Goals:
  - COXINEL aims to demonstrate that, by using laser acceleration, it is possible to obtain the free-electron laser (FEL) amplification needed to develop more compact light sources.
  - FEL are the first tunable X-ray lasers and the most intense light sources in the X-ray energy domain.
  - COXINEL benefits from a very favorable environment at SOLEIL and more widely on the Paris-Saclay campus, particularly in terms of engineering, to turn the ideas and theories that physicists have devised into reality.
- Closely connected to project X-5 in LOA.

European Research Council

ICAN Project

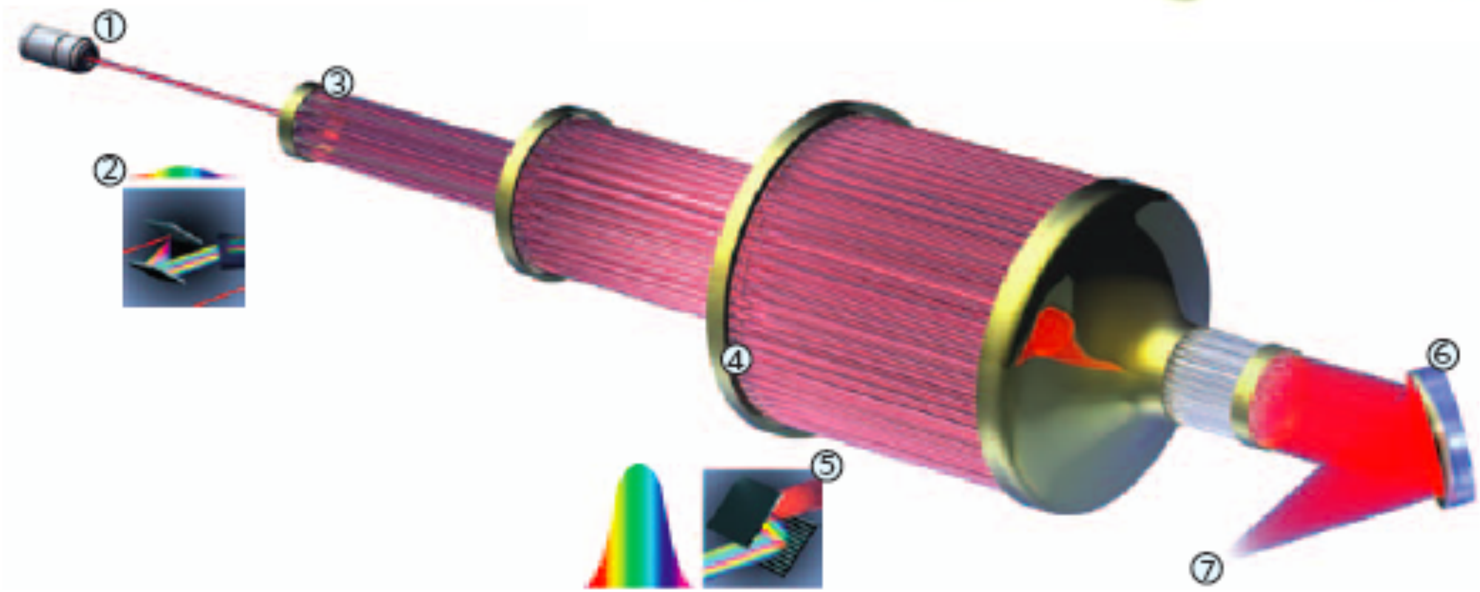


Figure 1 | Principle of a coherent amplifier network. An initial pulse from a seed laser (1) is stretched (2), and split into many fibre channels (3). Each channel is amplified in several stages, with the final stages producing pulses of ~1 mJ at a high repetition rate (4). All the channels are combined coherently, compressed (5) and focused (6) to produce a pulse with an energy of >10 J at a repetition rate of ~10 kHz (7).

G. Mourou

Coherent Amplification Network

The future is fibre accelerators

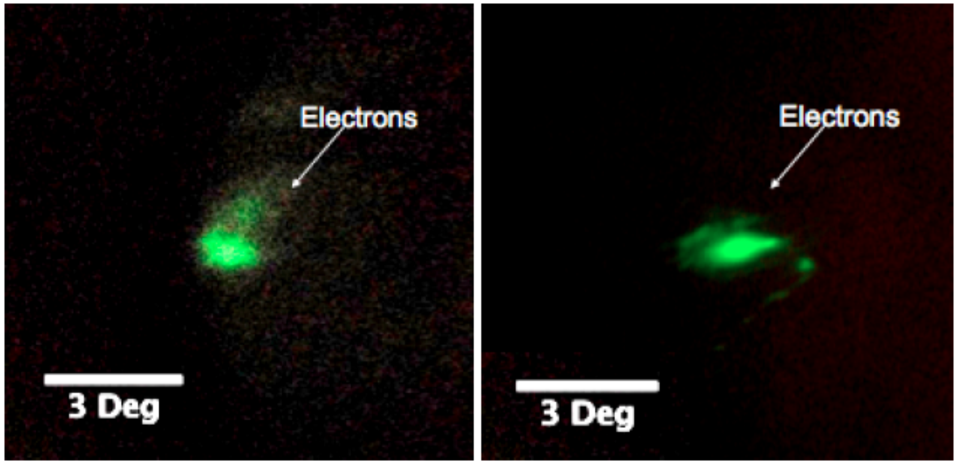
Gerard Mourou, Bill Brocklesby, Toshiki Tajima and Jens Limpert

Could massive arrays of thousands of fibre lasers be the driving force behind next-generation particle accelerators? The International Coherent Amplification Network project believes so and is currently performing a feasibility study.

SPARC LAB, Frascati, Italy

- Electron beam: 150 MeV, multi-bunch, bunch length below 300 fs, 200 pC, 1 μm norm. emittance
- FLAME laser: Ti:Sa, chirped pulse amplification (CPA), 200 TW, 25 fs long, 10 Hz repetition rate, wavelength 800 nm
- SPARC LAB is a multi-purpose user facility. Incudes experiments on laser- and beam-driven plasma wakefield acceleration experiments. See example of laser-generated electrons.
- Comb project is unique: resonant beam driven plasma wakefields.

M. Ferrario

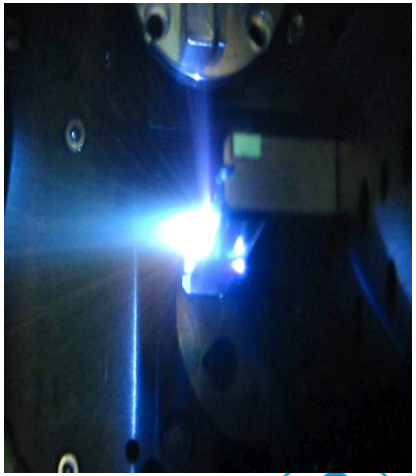


LUND Laser Center, Sweden

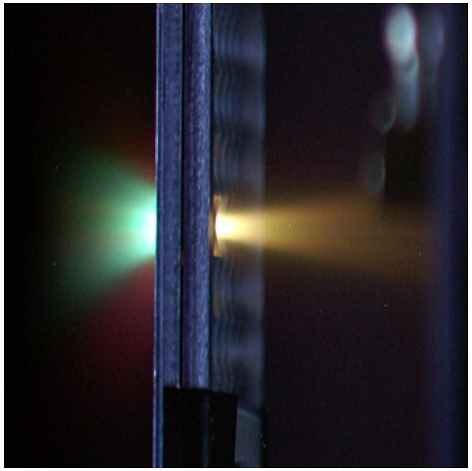
- Well established lab, since 1992.
- Laser: 60 TW + 5 TW + 3 TW (three separate compressors). Emphasis on:
  - Stability (pulse-to-pulse)
  - Reliability (day-to-day)
  - Contrast (ex. plasma mirrors)
  - Beam pointing (active control)
  - Wavefront (adaptive optics)
- Limited by manpower.

C.G. Wahlstroem

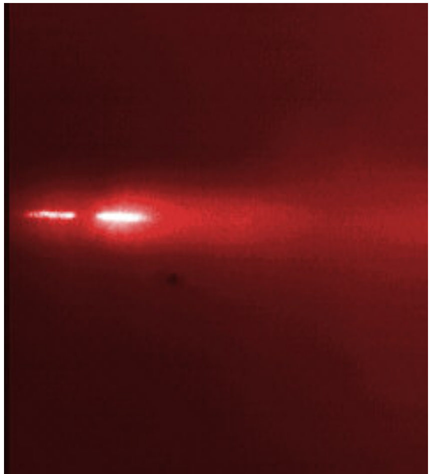
X-rays



Protons



Electrons



ELI Beamlines, Czech republic

- Laser: 10-15 fs duration, up to 10 PW. End stage: a few kJ in 15 fs (~200 PW) with low repetition rate (minute based).
- Might be the big player in some years.
- New techniques for medical image-display and diagnostics, radiotherapy, tools for new materials developing and testing, latest in X-ray optics, etc.
- Laser-accelerated, versatile electron and proton/ion source emitting in an unprecedented energy range (1 GeV to 100 GeV). Provide a major contribution for the development of future high-quality and low-cost proton sources for cancer therapy.

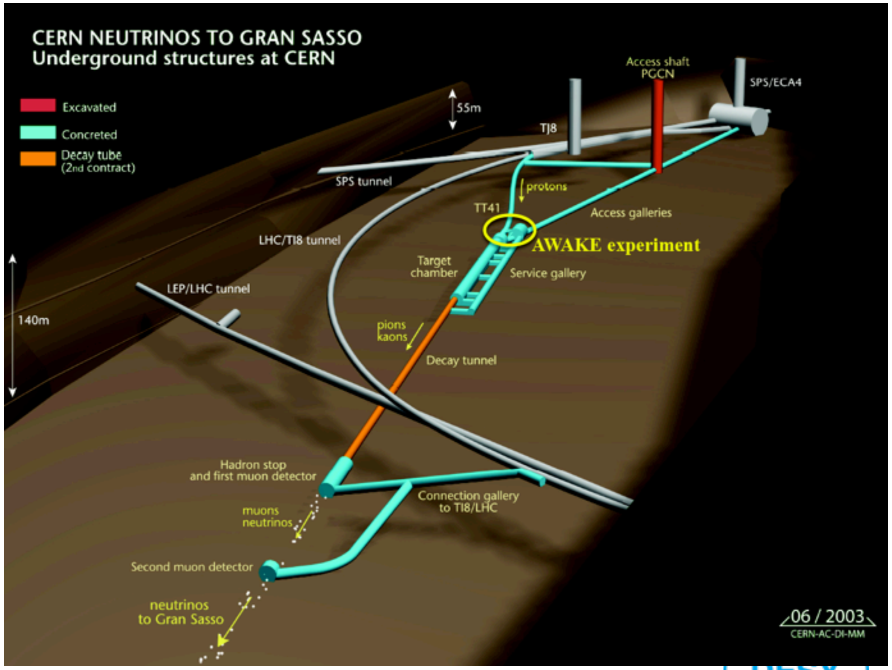
G. Korn

AWAKE experiment, CERN

- International collaboration with approved experiment at CERN beam.
- Driver: 450 GeV proton bunch, 1e11, 3.5μm emittance, bunch length >> plasma wavelength
- Modulation experiment:
  - The first parts of the proton bunch induce a plasma wakefield that starts self-modulating the later parts of the bunches.
  - Microbunching starts happening:
    1) Protons at focusing regions survive.
    2) Protons at defocusing regions get lost.
  - Surviving microbunches induce wake-fields.
  - Accelerate injected electrons from several 10 MeV to GeV.

A. Caldwell

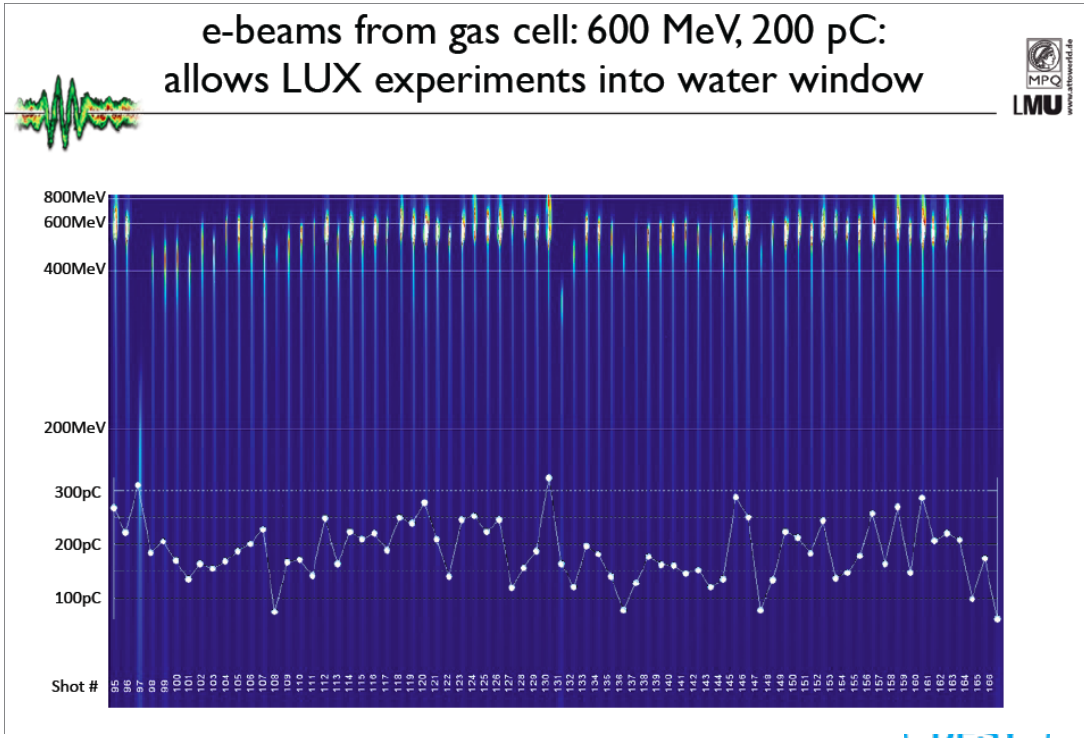
M. Wing



CALA Project, Munich, Germany

- Builds on expertise at MPQ and LMU.
- Successful in laser-driven generation of electron beams. See example with MPQ lasers.
- Ongoing: 63 M€ investment. Financed by State Bavaria and Germany.
- CALA completion: 2015…

S. Karsch



Strathclyde in UK/Scotland

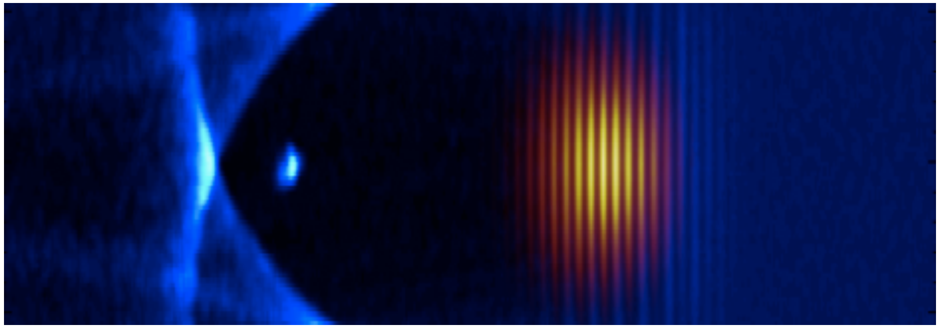
- SCAPA = Scottish Centre for the Application of Plasma-based Accelerators
- LWFA for generation of particle beams (electrons, protons, neutrons and light ions) and radiation pulses (THz, infra-red, X-rays and gamma rays).
- Experimental and theoretical research into high-power laser-plasma interactions.
- ALPHA-X Project: A Laser Wakefield Accelerator Dedicated to the Production and Application of Ultra-short Electron Bunches and Radiation Pulses.

D. Jaroszynski

B. Hidding

Z.M. Sheng

STFC – CLF and John Adams Institute in UK



- STFC Central Laser Facility used also for LWFA.
- John Adams Institute: Imperial College London, Oxford University, Royal Holloway, University of London.
- Plasma accelerators and novel sources of coherent x-rays. LWFA, narrow energy spread. Resonant LWFA. Medical imaging.
- Training of accelerator specialists, also in advanced methods.

S. Hooker

Z. Najmudin

A. Seryi

R. Walczak

Cockcroft Institute and CLARA Project

- Cockcroft Institute: Universities of Lancaster, Liverpool and Manchester, the Science and Technology Facilities Council (STFC at the Daresbury and Rutherford Appleton Laboratories), North West Development Agency (NWDA).
- Ultra-short pulse generation. FEL design and industrial applications → CLARA project. Plasma acceleration.
- Training.

J. Clarke

C. Welsch

S. Smith

Plasma Acceleration at Hamburg: LAOLA

- Laser: Ti:Sa 200 TW, 25 fs pulse length, 5 Hz repetition rate
  - Initially: Laser-driven wakefields in REGAE. LUX exp. towards FEL.
  - Later: Move to SINBAD facility.

F. Grüner

A. Maier

- Beams:
  - **REGAE**: 5 MeV, fC, 7 fs bunch length, 50 Hz

FLASHForward

  - **FLASH**: 1.25 GeV, 20 – 500 pC, 20 - 200 fs bunch length, 10 Hz.
    Beam-driven plasma wakefields. Beam-driven plasma wakefields with shaped beams and innovative injection methods. Helmholtz VI with UK collaboration.

J. Osterhoff

  - **PITZ**: 25 MeV, 100 pC, 20 ps bunch length, 10 Hz.
    Beam modulation experiment in a plasma cell, preparation to CERN experiment AWAKE

F. Stephan

  - Future **SINBAD**: 100 MeV, 0.01 – 3 pC, down to 10 fs bunch length, 10 – 1000 Hz

S hort IN novative B unches & A ccelerators at D esy

DESY Accelerator Research and Development (ARD)
SINBAD
Short INnovative Bunches and Accelerators at Desy

ARD top class research in existing infra-structure (discont-inued DORIS)

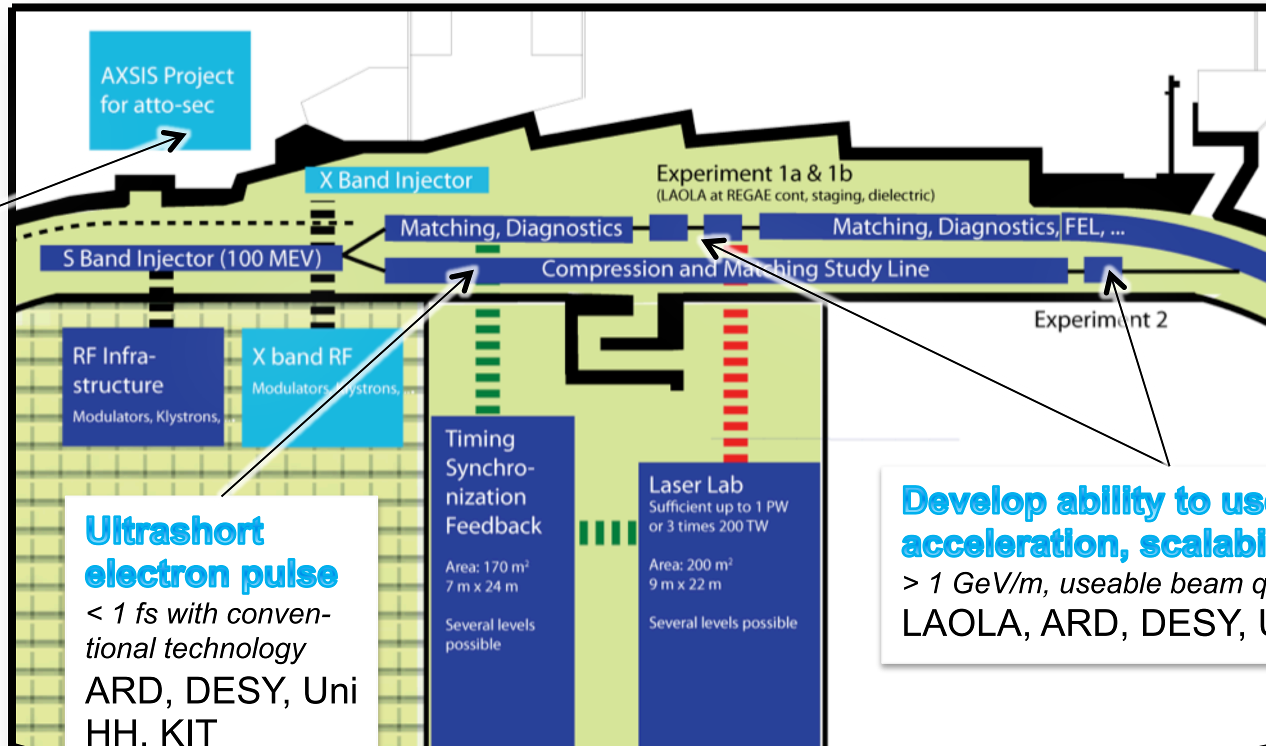
Compact Atto-Second Light Source
50 as, ICS
ERC Synergy Grant 14 M€, DESY, Uni HH, Arizona

European Research Council
Established by the European Commission

P. Fromme *F. Kärtner*

R. Assmann *H. Chapman*

PIER

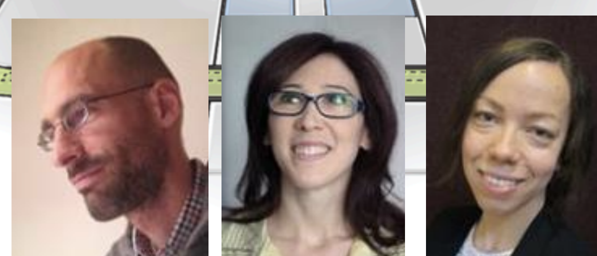


Ultrashort electron pulse
< 1 fs with conven-tional technology
ARD, DESY, Uni HH, KIT

Develop ability to use plasma acceleration, scalability
> 1 GeV/m, useable beam quality, FEL?
LAOLA, ARD, DESY, Uni HH

Footprint: 90 m x 50 m

Room for further phases and users
Third party funding, interest from ELI, …



DESY